WITH HER EYES EVER FIXED ON HIGH

THE SPIRIT OF THE SUMMIT — BY LORD LEIGHTON

The Book of

POPULAR SCIENCE

The Wonders of Modern Discovery
The Triumphs of Inventive Genius
The Story of all Created Things and
the World They Live In

EDITED BY

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VOLUME
III

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THE TRACING OF THE EARTH'S ORBIT

THOUGH in our survey of the universe, which is the field of all science, popular and unpopular, present and to come, we included mind as well as matter or energy and ether, we are to take no further cognizance of mind here. This is not because it is less important; on the contrary Nor is it because there is no science of mind, the rather have we paid formal homage to mind in this section, since students of the universe have too often ignored it in their surveys, and have laid themselves open, most justly, to the charge of materialism.

Nevertheless, here we shall have no further direct concern with mind, for our purpose is to study the physical universe, to discover and investigate the physical laws by which it is governed, and to coordinate all these, as well as we can, into one consistent system which indeed flows from intelligence but is not itself intelligent. Thus we see the movements of the planets and the moon, and the rotation of the sun; the daily rotation of our own planet is no less certainly to be inferred On further inquiry we discover that there are shooting stars and comets which move, and that the "fixed stars," as our fathers called them, are all in motion, fast or slow, some towards us, some away from us, others in all other directions. These movements are in part so little comprehensible that they may appear chaotic and ungoverned On the other hand, some of them, such as the movements of the planets, are regular and systematic, as if under intelligent guidance. Are we, then, to say that things are largely a higgledy-piggledy, but that here and there the working of a rational intelligence can be observed?

Modern science agrees with sound philosophy in denying any such incomplete working of intelligence in the universe The apparent chaos of starry movement is only apparent, not real. It is the expression of order hitherto undiscerned The apparently purposeful and deliberate movement of other heavenly bodies is not the result of any intelligence or will in those bodies nor of the direct action of any intelligent agents appointed to guide and urge them onward in their courses. The movement of the stars as well as of the planets is the expression of the uniform working of mechanical laws And, beyond these denials, science enables us to make the positive affirmation that, whatever else be dubious, this stands: order is everywhere in the universe, the hall-mark of intelligent authorship is indelibly stamped on all its parts, so that the universe witnesses to the existence and power and wisdom of God, its maker and upholder

Science makes its highest as well as its primary and fundamental claim, when it affirms that the world of sense and apprehension is orderly and entire, not unsuited to represent to us a Mind which is orderly and entire, and that the action of the hand of God is apparent not only in some particular works of nature, but always and everywhere.

These are fundamental philosophic considerations which we need to have in our minds when we approach the problem of explaining the movements of the heavenly bodies. Nor can we better realize the difference that these ideas make to us today than by recalling the theory of the heavens which was maintained by, for instance, the great astronomer Kepler.

Kepler knew nothing of the movements of the "fixed stars," or of the movement, as we now realize, of our own sun through space. To him they were indeed fixed, and with them he contrasted, as so many have done before and since his day, movements of those bodies which the ancients called the planets, or wanderers. Kepler was born late enough in time to accept the teaching of Copernicus, and include our earth in the category of planets. He was the supreme student of the motion of the planets, the order and uniformity of which he discovered. But his philosophic ideas were other than ours.

JOHN KEPLER, THE GERMAN ASTRONOMER
Who discovered that the earth moves round an elliptical orbit, now nearer the sun and faster, now further away and slower

It is recorded of him that, being asked by his wife what he had been doing all the hours of "star-gazing," he replied that he had been "thinking the thoughts of God after Him." A noble reply, yet, as perchance we shall duly see, not altogether true in the sense in which he understood it. His theory of the universe involved the belief that the fixed stars were where God had put them; and that the planets, the order of whose movement he had discovered, were impelled and maintained in their orbits by heavenly beings, the agents of God, whose "thoughts" their movement expressed.

How the advance in knowledge makes for our understanding of the ways of God

Further advances in scientific knowledge have enabled us to realize that the stars are not fixed and that the motions of the planets are not due to intelligent agents of God guiding their courses but to the mechanical forces implanted by Him in all His material creatures. Thus, we see that the planets are in themselves more perfect than they were thought to be by Kepler, since they require no external guidance and no urging onward beyond that which is implanted in their nature. Thus the advance of science enables us to understand better the ways of God in governing the universe.

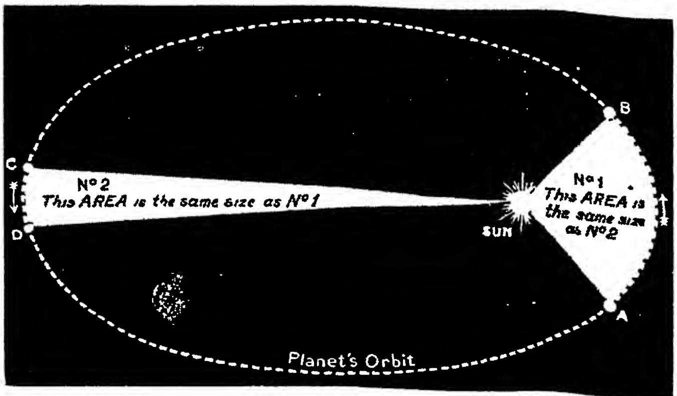
Men whose idea of the universe was largely built upon *a priori* reasoning rather than on careful observation were offended at Galileo for descrying spots upon the majestic face of the sun. Men of a similar type were entirely indisposed to consider any additions to the number of the sun's family, because the perfect number is seven, and such must be the number of the planets. Yet again, just as the sun must be spotless, and the number of his family the perfect number, so their movement round him (if, indeed, we are to admit that the planets, including the earth, do move round him, and not all things round the earth) must at least be itself perfect. Now, there is only one perfect figure on this theory of perfection, and that is the circle. Therefore, the planets, perfect in number, must move round the spotlessly perfect sun, in the perfect figure of circles, and with perfectly constant speed.

It is, perhaps, easy enough to ridicule such assumptions today, especially since most of those who ridicule would then have been found among the number of the ridiculous.

But we must remember that, with all this imperfection of reasoning and consequent error in matters of science, there was, in almost every case, a sincere desire to glorify God, and that the indignation of such men against those who controverted their evidence of perfection was for the most part sincere and admirable in spirit.

Now, if the planets move in circles round the sun, at constant speeds there is no more to be said The thing is so, because it is so, and that settles the question Nothing deeper nothing wider, is involved But we may find a deeper and wider perfection even than that of the "perfect" figure, if we look into the facts, and discover that the figures described by the planets are not "perfect" at all — in this very imperfect sense

John Kepler was born in 1571, and was nearly forty when, after the long years of that labor for which his wife's patience seems to have been less adequate than his own, he announced, on the strength of his study of Mars, that the orbit of a planet is not a circle but an ellipse At this time, and ten years later, he also announced two other laws, making, with the first, Kepler's three laws of planetary motion, upon which, as the basis for the law of gravitation, soon to be discovered by Newton, modern astronomy may justly be said to rest



THE CHANGING PACE OF THE EARTH ROUND ITS ORBIT

This diagram illustrates one of Kepler's laws A line drawn from the sun to the earth takes the same time to pass over the area No 1 as it does to pass over the equal area No 2, the motion of the earth being swifter between A and B than between C and D

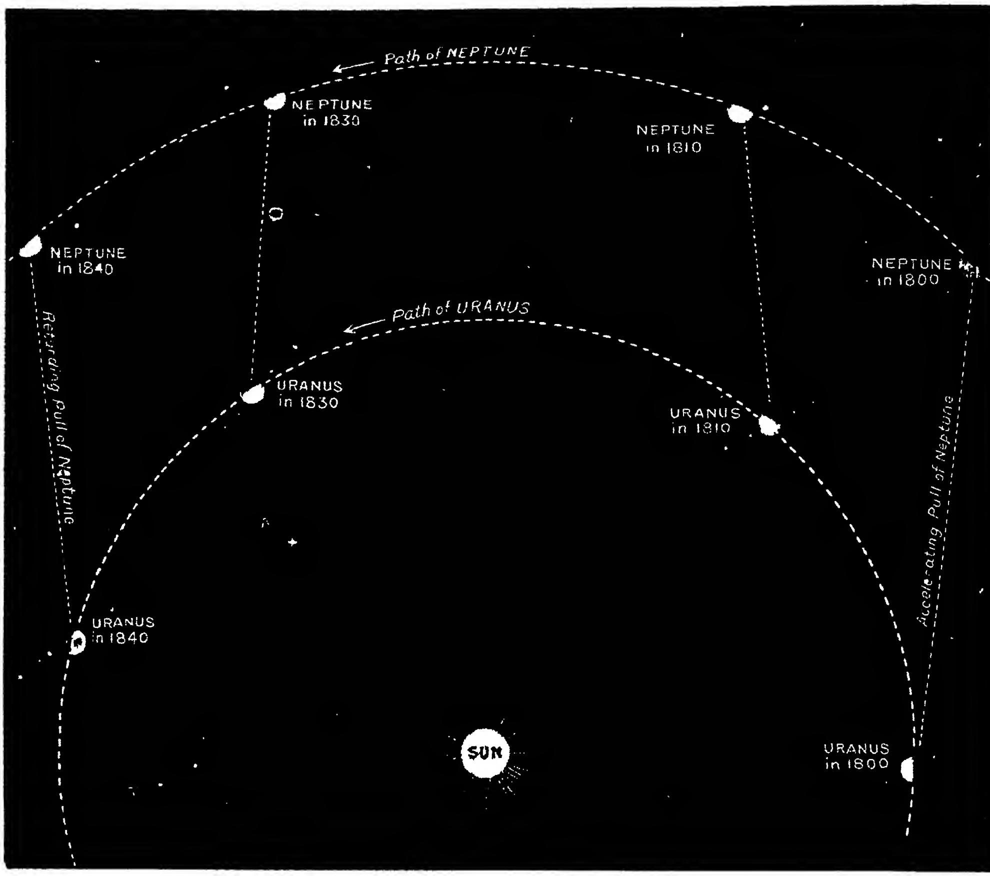
These three laws are, first, that the planets move, not in circles, with the sun at center, but in ellipses, with the sun at one focus (of the two which an ellipse possesses), second, that, as a planet moves round the sun, the line from sun to planet passes over equal areas in equal times, which means that the planet must move more rapidly when nearer the sun than when further away; and third, that there is a constant relationship between the time that a planet takes to go round the sun and its distance from the sun.

These are the three great laws of planetary motion, of which we may say, with equal truth, that the law of gravitation is inferred from them, or that they can be deduced from the law of gravitation It is Newton's supreme fame that, pondering on these things, he replaced Kepler's celestial spirits, which urged and steered the planets in their orderly course, by an inherent force of gravitation, directed to or from the sun, and acting along the ever-moving line between the planets and the sun This force it is that controls the planets, as it controls the moon But his law, local in its original application, far transcends the solar system, of which it is the key. It asserts that

"Every particle of matter in the universe attracts every other particle with a force in the direction of a straight line joining the two, whose magnitude is proportional to the product of the masses, and inversely proportional to the square of the distance between them"

We must briefly note the various clauses of this law before we consider its meaning. It shows us that gravitation is not the pull of the earth for the apple, or the sun for the earth, any more than it is the pull of the apple for the earth, or the earth for the sun. Big and little, all alike attract each other The result will show itself in the motion of *both*, but this motion will amount to more where there is less to move The earth rises to the apple, but the movement is infinitesimal, and all we notice is that the apple drops to the earth.

Further, the discovery that the attractive force, in the solar system, centers in the sun is superseded by the law which asserts that all matter attracts all matter. It is merely the huge mass of the sun that makes its rôle so obvious But, according to this law, the planets attract the sun, as the sun attracts them; and they attract each other.



THE DISCOVERY OF A NEW PLANET BY MATHEMATICS — A TRIUMPH OF THE HUMAN MIND

This drawing explains how mathematicians were able to infer the existence of a new planet, which was afterwards found in the precise place expected It was observed that the planet Uranus traveled much faster and farther between the years 1800 and 1810 than between 1830 and 1840, and it was imagined that this was due to the pull of a then unknown planet, which accelerated the motion of Uranus at the earlier date, and then retarded it after Uranus had passed a particular point in 1822 Mathematical calculations led a great astronomer to turn the telescope to a particular place in which the unknown planet was supposed to be, and there, in 1846, the planet Neptune was discovered, a thousand million miles beyond Uranus, and more than twice that distance from the earth

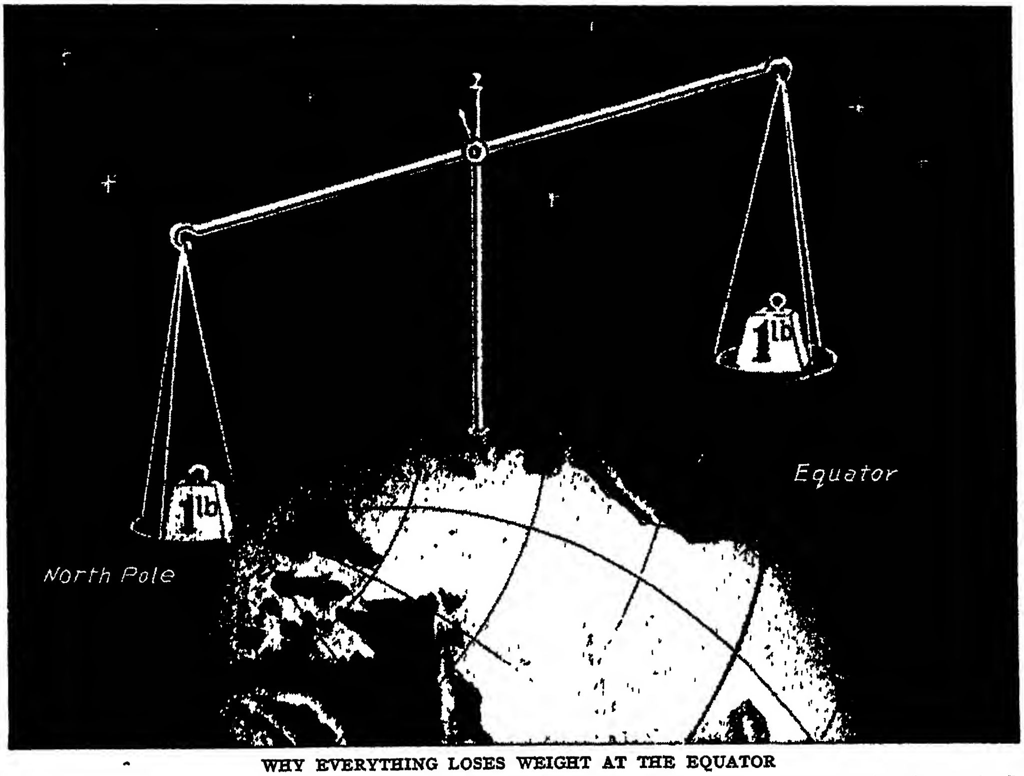
Kepler's statements of planetary motion, therefore, are not strictly accurate, for this motion is complicated by the attraction of the planets for each other. They do not move as if under the influence of a force solely centered in the sun Thus the planet Uranus was found to behave in a somewhat different way than it should strictly according to Kepler's laws, as if some other unknown celestial body were complicating its motion. If the law of gravitation simply asserted that the sun attracts the planets, it would not be the key to this case, but it asserts that all matter attracts all matter. Hence, the presence of another body, outside the sun, might be inferred to account for the abnormalities in the movement of Uranus.

Two astronomers made the necessary calculations assuming the truth of Newton's law, and they were duly rewarded by the discovery of the hitherto unknown planet Neptune, according to their predictions. This was alike one of the most notable achievements of science, and the most perfect imaginable illustration of the ideal methods of knowledge — which are the combination of the method of deduction from general to particular, with the method of observing particulars, and inferring from these the general law to which they conform.

If we do, indeed, realize the universal character of Newton's generalization, and how incalculably it transcends the mere notion that the sun attracts the planets, or

the earth the apple, we may note next the clause which declares that the force of gravitation is exactly measurable, and is proportioned to the quantity of matter in action. Thus if we consider any two bodies, one known and the other unknown, and try to study the force of gravitation between them, we must observe the motion of the body we know, and since all variation of motion involves the action of force, we can infer the gravitational force at work to produce the motion we observe. But if we know the position and mass of the body we see, we are now enabled by the law of gravitation to infer the position and mass of the body we do not see, if we also take into account the law as to distance which concludes Newton's statement. This is the fashion in which Neptune and also the dark companions of many stars have been discovered, and in this way too we may later on discover a possible planet outside Neptune, such as some astronomers are now suspecting to exist.

Observe that Newton's law speaks not of weight but of mass. To understand the distinction is essential for all this department of science. The mass of anything is the quantity of matter in it. This is a fixed amount, so to speak, of the thing in question and remains unchanged as long as nothing is added to or taken from the body. This is strictly true in the Newtonian sense, though modern research seems to indicate a very slight increase in the apparent mass of a body — that is, in its inertial effects — when it is moving at enormously high velocities. The weight of a body, on the other hand, is the measure of the force of attraction existing between it and the earth, or to speak more generally, between it and the celestial body on which it happens to be placed. It is therefore something changeable. It is due to gravitation and depends not only on the mass of the body itself but also on the mass of the attracting body and on the distance between them. If we hold a mass in our



WHY EVERYTHING LOSES WEIGHT AT THE EQUATOR

The earth bulges at the equator and is flattened at the poles, the distance from the North Pole to the center being about 13½ miles less than the distance from the equator to the center. The pull of gravitation is less at the greater distance, and so a balance with one pan at the pole and the other at the equator would show that of two *equal masses* the one at the equator would have *less weight* than the one at the pole.

hand the pull between the body and the earth causes us to feel a pressure on our hand and this pressure is what we call the "weight" of the body. Mass is the amount of matter in a given body and remains just so much, independently of the position of the body and of the presence of other bodies, but weight is affected by other bodies and may increase or decrease for the same mass.

Thus the weight of a thing always and everywhere depends on two factors besides its own mass — namely, the mass of the attracting body and the distance between the two bodies. The earth being somewhat flattened at the poles, and bulging somewhat at the equator, anything weighs heavier nearer the poles, and lighter nearer the equator, because when near the equator it is further from the earth as a whole, or from the center of the earth.

The difference of weight in equal masses at the equator and at the poles

Thus the man who carries gold from Alaska southwards, and weighs it at both places in a spring balance might be accused of having stolen some of it, for a spring balance will show that it weighs less when nearer the equator, being less pulled upon, though it is still all there. In the same way cubes of metal, exactly similar in mass, may be made in the laboratory. Placed side by side, they will weigh the same, but if either be placed upon the other the uppermost will weigh a tiny bit less, for it is now a tiny bit further from the earth.

Thus our weight diminishes as we walk up hill, not merely because we perspire, but because, even if our mass remained the same, it would weigh less, being the subject of less gravitational pull. Yet again, to jump six feet high on the earth is a great and rare feat. To do so on the moon would be nothing, for the moon is so small that her pull is much less; but to do so on Jupiter would be utterly impossible for us, for even if Jupiter were cool enough and solid enough for us to stand on it, it is estimated that our weight there would be almost three times as great as it is on the earth.

Newton's application to a part of nature of a great law which is universally true

But we must first note the last clause of the law, before we consider the tremendous meaning of one all-important word which is omitted from the law, but implied therein. Newton tells us that the force of gravitation varies inversely as the square of the distance. Thus, if we increase threefold the distance between two bodies, the force of gravitation between them will be reduced to one-ninth of its former quantity; a twenty-fold increase of distance would reduce the force to one four-hundredth, and so on. If we ask why this should be so, we do well first to ask whether it is so in any other case. At once we find that, as Newton could not know, the "law of inverse squares," as it is often called, is a law of general application.

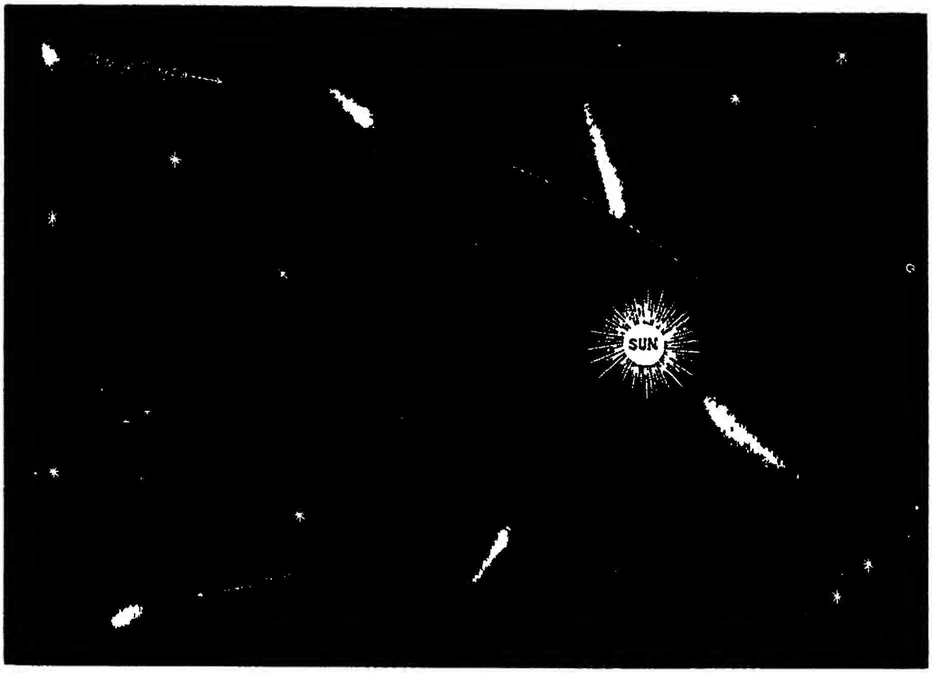
Let us take the case, for instance, of the intensity of light. If we double the distance of a piece of paper from a candle, the light will now cover not twice but four times the area covered before, and the intensity of the light, at twice the distance, will be one-fourth of what it was. This law of inverse squares applies to the intensity of gravitation, light, heat, sound, electrical and magnetic attraction, and we may expect it to apply in general to the distribution of all or any forces that spread themselves equally outwards in all directions.

The great words everywhere and always that give sublimity to natural laws

The one tremendous word that has been omitted from the law of gravitation, as usually stated, is "always." This force acts continuously. Light, heat, sound, and many other manifestations of power may wax and wane. There may be intervals of darkness or silence, or, at the least, pulses in their action. Gravitation acts *always*, and is always constant. Its force never fails and never varies. Innumerable experiments may be made in the attempt to influence gravitation, but they all "fail," as we say, meaning that they succeed in showing us the truth.

A discovery that would transcend all past achievement in the physical realm would be that which enabled us to control gravitation, as we control the lighting of our rooms by touching a switch Scarcely less effective would be the discovery of some obstacle that gravitation could not penetrate We may measure the gravitational force exerted between two bodies, and then try to modify it by the interposition of obstacles, by the formation of a vacuum between them, and so forth It makes no difference Let us change the mass of either body ever so slightly, or alter the distance between them ever so slightly, and the result is certain and constant; but nothing else that we can devise or imagine affects their mutual gravitation in the slightest degree. Change of temperature or pressure, or physical condition, or chemical combination or separation, or magnetism, or what you will, does not influence this force. So much further, then, are we from being able to abolish gravitation altogether, even for a moment, or to delay its action by the most infinitesimal period of time.

This last clause is noteworthy; and the assertion that we cannot delay the action of gravitation is not to be taken as meaning either that gravitation takes time, or that, if it does, that time can never be modified. Obviously, the question is of tremendous importance, for if gravitational force required any time to travel, even though its speed were that of light, the consequences in the tremendous distances of starry space would be stupendous So far as can be ascertained at present, gravitation has no speed, for it is instantaneous. Distance duly and rigorously affects its force, according to the law we have noted, but otherwise appears not to exist for it.



THE OUTWARD PRESSURE OF THE SUN'S RADIANT ENERGY

When a comet is far from the sun it appears a shapeless patch of light, but as it approaches it develops a streaming tail of light that looks as if it were blown away from the sun This effect is supposed to be produced by the repelling power of the sun's radiated energy

The greatest speed we know is that of light and radiant heat and electric waves in general, which travel through the ether at a rate of more than 186,000 miles in a single second of time. Fast though this be, it involves thousands of years when we contemplate the distances of space Everything would be different if gravitation required even such an unthinkable speed as this, but, so far as we can discover, it has no speed at all. It is simply there.

Men of science never cease to wonder at the strange misconceptions of science which are entertained by the most illustrious men whose business it is not. Tennyson was a great poet, a great thinker, and a life-long student of science, of whom Huxley declared that no poet since Lucretius had so realized the meaning of the message of science to the world Yet Tennyson asked Huxley how the ascent of the sap in a plant could be reconciled with the law of gravitation

Kingsley was a great writer and a noble thinker, but he was once involved in a controversy with men of science, in which he declared that when he held an apple out in the palm of his hand he "defied" the law of gravitation.

The rise of the sap in a plant, of a bird, a ball or an airplane in the air, or the blood coursing upwards through one's neck to one's brain, or the maintenance of the apple in one's hand — neither these nor any other fact that can be named is either incompatible with gravitation or "defies" it The man of science cannot but gasp at what seem to him to be such incomprehensible misunderstandings.

The law asserts the existence of a constant force acting between things But the world displays many forces, of which this is only one The bird, the ball, the flying-machine, set one force or another to act in the opposite direction to that in which gravitation acts, and the results are in due accordance with the proportion and direction of the forces involved in each case — of which gravitation, the sleepless and unweary, is but one.

If you hold an apple out in your hand, and decree that it shall have no weight, then verily you defy gravitation. If the gull which some hunter has shot and killed does not drop, then, indeed, the law of gravitation is defied. If an airplane could soar and remain aloft in a vacuum, and without spending any energy, then, indeed, the law would be no law. But if anyone will show us how to turn the gravitation on and off, as one "turns the light on," certainly the world will be a new place henceforth, though whether habitable by the inventor or anyone else we question.

The unfailing power that interweaves the web of the universe

Not merely is gravitation only one of the forces of the universe, but it is by no means a very powerful force, according to our usual standards of such estimate Molecular forces, such as cohesion and capillarity, may readily suffice to cause the ascent of the sap in the plant, against the pull of the earth, and without in any way justifying Tennyson's doubt.

But in this, as it is in all other cases, gravitation is acting all the time, and the sufficient and constant demonstration of its constancy is to be found in the work which must invariably be done if we wish to accomplish or arrest any movement against the line of its action To assert that this force is universal and unfailing, never to be caught napping or reckoned without, is not to say that it is the only force in the world.

If it were so, how should the earth or any other planet be maintained in its orbit? According to Newton's law, there is an attractive force between sun and planets; Tennyson might just as well have asked how the law of gravitation is compatible with the fact that the earth does not rush headlong to the sun, but travels round it from age to age. The answer is that the motion due to the force of gravitation is only one of the motions involved Our ancestors used to speak of "centrifugal," or center-fleeing, and "centripetal," or center-seeking force They said that the earth keeps in its course because the center-seeking and the center-fleeing forces balance. The terms are poor, and the explanation inadequate.

Newton taught us to see a force attracting sun and planet (though the planet does not move in a circle, and there is thus no center to seek); and he also taught us, in virtue of his "first law of motion," that the planet, like every other moving body, tends to move "straight ahead" at a constant speed forever. This is not a center-fleeing or "centrifugal" force, but the expression of the law of inertia, which says that moving things move steadily on it nothing prevents them.

Why the sun, moon and stars do not rush together in one mass

Thus, if the force of gravitation were arrested, a planet, in virtue of Newton's first law of motion, would fly from its orbit, not away from the sun, as the old term "centrifugal" would suggest, but in the line of its motion at the moment when gravitation ceased — "off at a tangent," as we say, like the drops from a twisted umbrella or a stone from a sling

On the other hand, if something arrested the forward motion which is in the planet, so that it stood still for an instant, then from that moment onward the force of gravitation alone would be effective in determining the motion of the planet which would therefore fly headlong to the sun.

But to suggest that gravitation is not acting when its action is complicated by other forces is to miss the whole point. Gravitation acts on the ascending sap or blood or airplane or bird as much as when they fall slowly or quickly. We think that gravitation only acts when we see the bird descend, but that is really because we don't think. If its tendency to draw all bodies together was the only one in nature, all the matter in the universe would become huddled in one dense heap, moons rushing to planets, planets to suns and suns to one another and all these to their common center of gravity. But there are other tendencies at work, such as the motion which the planets possess in virtue of their inertia; and the just comprehension of the law of gravitation is Herbert Spencer's, who described it as the law which tells us how the heavens are balanced.

The recent students are showing us that, under certain conditions, the radiation-pressure from a hot body, such as the sun, may be greater than the gravitational force towards it, large though it be; and thus the sun may violently repel particles of matter in certain states — as, say, the tenuous tails of comets, which are well known to be produced as comets approach the sun, and to be directed away from the sun, whether the comet is approaching or retiring.

The shrinking sun flings forth heat rays which repel approaching comets

Nevertheless, if the constant force of gravitation, though not so insuperable as we had unthinkingly thought, be unantagonized, it may do amazing things. Its continuous action in the substance of the sun must involve a steady shrinkage, with consequently increasing density, of the solar body But this gravitational shrinkage will involve friction, and the production of heat and light; and so it seems, or has seemed to many including no less an authority than Helmholtz, that the whole of the sun's incessant output of light and heat might be accounted for by it

Further, we may now note the remarkable fact, perhaps not hitherto observed, that the sun's gravitational shrinkage produces the radiations whose pressure acts in the directly opposite way to gravitation. Thus, also, perhaps may a certain rhythm of the universe be partially maintained.

The unanswered question of universal force: What causes gravitation?

When all this has been said, and vastly more which the mathematicians might add, and when modern astronomy has been appealed to, never in vain, for unending illustrations of the truth of Newton's law and the universality of its action, there yet remains the unanswered if not unanswerable question: What causes gravitation? The theories are very numerous and modern students of electricity are by no means hopeless of solving the mystery.

At least one great discovery has been made since Newton's day, and that is expressed by our modern conception of the ether, the universal something which is the medium of gravitation. But the reader who has already surveyed that subject will realize how many steps must yet be taken before we can hope to discover the cause of this mystery of gravitation.

Plainly, we must first understand matter and the ether, and the exact relation between matter and the ether, before we can hope to explain the force which all particles of matter exert upon all other particles through the ether.

THE WONDER OF A DROP OF WATER

These pictures show many of the forms in which we find water, a universal essential of life Water can be made into dew, hoar frost, hailstones, snow, mist, rain and ice, as shown in these pictures, yet it is always water, composed of the same elements, retaining its original weight through all these transformations.

THE EARTH'S FOUNDATIONS

New Knowledge of the Elements and the Amazing Things that Happen when They Come Together

THE THINGS THE WORLD IS MADE OF

IN discussing the making of the earth we have seen that certain substances known as "elements" enter into the composition of its crust, but so far, we have not considered what we mean by element By element we mean a simple, pure substance that by no known means has as yet been divided into parts with different properties. For instance, if we take the red substance known as mercuric oxide, and grind it into a powder, each grain still remains mercuric oxide, there is no difference between one grain and another. Is mercuric oxide therefore an element? Perhaps!

But we have not yet done our disruptive worst Let us try the ordeal by fire Let us heat it When we do this we find that it is shaken to pieces, and that it divides into a heavy vapor which condenses as the liquid metal mercury and the gas oxygen, which supports combustion. Mercuric oxide, therefore, is not an element; it is a compound of two substances which it is possible to separate. But when we take the two separated substances we may roast them, and freeze them, and electrify them, and do what we will with them — they still remain mercury and oxygen, a liquid metal and a gas, each with certain fixed, definite qualities. We say, therefore, that oxygen and mercury, as far as we know, are elements.

Or, to take another instance, we get some tallow and divide it into small pieces. Each piece still remains tallow. We melt it, and it solidifies as tallow. We freeze it, and it thaws as tallow. Is tallow, then, an element? No, we must experiment further. Let us burn the tallow as a candle.

Lo! the tallow is now torn all to pieces. A black substance, carbon, separates out of the tallow, goes off with the oxygen in the air, and with it forms a gas called carbon dioxide; and a gas called hydrogen likewise comes forth from the burning tallow, links arms with the oxygen in the air, and goes off as water. So tallow is certainly not an element, but a very complicated compound, composed of several elements.

Or take water. We can heat water into steam, or freeze it into ice; yet it retains its chemical qualities as water, and gives rise to no substance with other than aqueous characters. And yet water is not an element either, for by passing it over red-hot iron or red-hot carbon, or by passing a galvanic current through it, water can be divided into two gases, oxygen and hydrogen, both of which are quite dry, and neither of which is in the least like the water which the two together form. Even a little piece of potassium laid on water will break up the water, keeping for itself all the oxygen and part of the hydrogen and liberating the rest of the hydrogen which will burn on account of the heat evolved by the chemical action. So water, in spite of all first appearances to the contrary, is not an element after all.

Only after a substance has resisted the most violent and ingenious efforts to pull it to pieces do chemists call any substance, whether gas, or solid, or liquid, an element. Even then it is better to be guarded, for chemists have frequently found out that substances which seem simple are really compound, and can be divided into parts chemically distinct.

For years and years, for example caustic potash was considered an element till the chemist Sir Humphry Davy succeeded in shaking it asunder by electrolysis, and showed that it was really a compound, and that an unknown metal — now known as potassium — could be separated from it. Like most discoveries, this discovery led to more, and Sir Humphry soon broke up some other substances; he thus discovered the new element sodium and was the first to isolate strontium from its compounds and to prove that chlorine and magnesium were chemical elements. Since Sir Humphry Davy's day many new elements have been discovered, and there are now about eighty. Some of these were difficult to find because they were tightly combined in compounds. Some, like the inert gases in the air — neon, xenon, argon, krypton and helium — escaped notice because they occur in very small amounts, and have no chemical activity. None of these five atmospheric gases combine with other gases; they lead lazy lives, and do nothing to attract attention.

The little known elements, and the light given off by solid bodies

About half the elements are well known, and about half are hardly known at all. We have all heard of aluminum, antimony, arsenic, bismuth, calcium, carbon, chlorine, cobalt, copper, gold, hydrogen, iodine, iron, lead, lithium, magnesium, mercury, nickel, nitrogen, oxygen, phosphorus, platinum, potassium, radium, silicon, silver, sodium, sulphur, tin, and zinc. But how many people have heard of columbium or niobium, erbium, gadolinium, indium, lanthanum, neodymium, praseodymium, rhodium, samarium, terbium, thulium, ytterbium, yttrium, zirconium or europium?

Some of the rare elements have been detected in a most wonderful and interesting way by spectrum analysis. It is well known that the white light of the sun is really a mixture of colored waves of light, and that the colored waves can be separated from each other by passing the white light through a prism. All solid bodies, if heated to what is called white heat, give off similar composite white light that can be analyzed into component colored waves. But it is found that when any substance is raised to a state of vapor and rendered incandescent it no longer gives off white light, but certain characteristic colored rays which can be analyzed by a prism, and serve to distinguish the given substance from all other substances. Sometimes the colored rays can be discerned by the eye, and the colored lights of fireworks are easy objects for this rough eye-analysis.

The analyst who finds the 180-millionth part of a grain

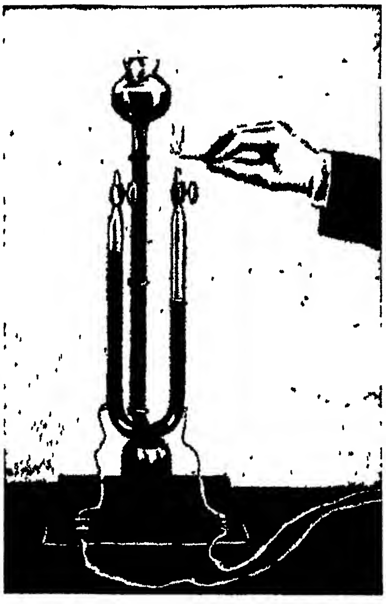
The scientific instrument for the analysis of the light of incandescent vapors by means of a prism is called a "spectroscope," and the analysis "spectrum analysis."

By vaporizing many substances at a moderately high heat and analyzing their light, the most minute traces of certain elements may be detected. For instance, one 180-millionth part of a grain of sodium, one 6-millionth part of a grain of lithium, one millionth part of a grain of strontium and calcium can be detected. In view of the wonderful delicacy of this mode of analysis, it is not strange that it led to the discovery of some of the rarer elements. In 1860 Professor Bunsen was making a spectroscopic examination of the deposit left after the evaporation of the Durkheim springs in Germany, and he noticed some bright lines he had never seen before. Taking the hint, the professor was led to search for new elements, and succeeded in finding cæsium and rubidium.

The instrument which identifies salt burning in the kitchen or in the sun

In 1862 Sir William Crookes discovered another new element which gives a magnificent bright green line through the spectroscope, which he therefore christened thallium, from *thallus*, the Latin word meaning a green twig. Two years later two indigo-colored lines betrayed another element to two German professors, who straightway isolated it and called it indium, because of its indigo light. Finally, in 1875, two violet lines led to the discovery of another new metal which its discoverer named gallium.

The importance of the spectroscope, therefore, in the identification and discovery of elements is undeniable, and a remarkable fact may be mentioned here However distant incandescent light may be, it can be analyzed by the spectroscope, and will give evidence of the element which produced it We can identify not only the salt "burning" in a kitchen fire, but the salt glowing in the furnace of the sun A substance incandescent in the sun 93 million miles away may be detected with as much certainty as if it were in the laboratory, and in this way we have found out the constitution of suns and auroras and nebulæ In our own sun we have discovered about half the elements known on earth, including iron, carbon, calcium, aluminum, sodium, potassium, magnesium, silicon, hydrogen, zinc, copper, silver, tin, and lead. Gold is not found in the sun, but some of the rare metals are plentiful, and helium was found in the sun before it was found in the earth In nebulæ an element, nebulium, has been detected which has not been found in the earth



BREAKING UP WATER INTO GASES

Water, which would at first appear to be an element, is not really so, because it can be split up into gases in the manner here indicated By passing an electric current through it, water is decomposed into two gases — oxygen and hydrogen In this instrument the hydrogen is collecting in the right arm of the tube and the oxygen in the left

Many of these elements seem very superfluous. We can see some use in carbon, hydrogen, oxygen, nitrogen, sulphur and phosphorus, since our own bodies and all the animal life and plant life of the earth are built up mainly of these elements. We can see some use in calcium, since our bones contain a fair percentage of it. We can see some use in sodium when we find it in our table salt. We can see some use in gold. But of what possible use can infinitesimal quantities of samarium, or thulium, or erbium be? The truth is that for many of the rare elements we have not yet found any use, while for some, either alone or in combination with other elements, we have found most unexpected uses.

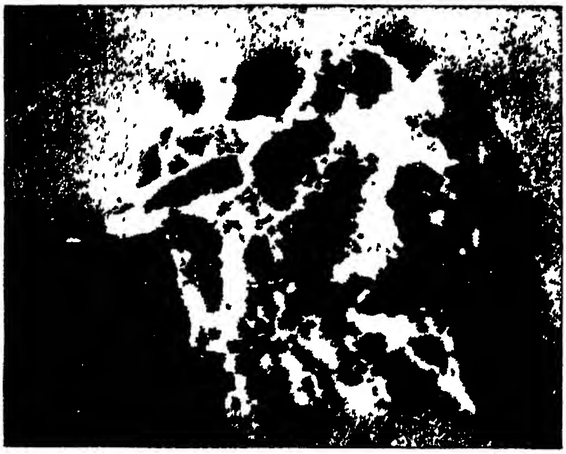
Take for instance an incandescent gas-mantle It is composed of oxides — compounds with oxygen — of the rare elements thorium and cerium, which are obtained from a peculiar sand in Brazil and from fairly large deposits in North Carolina. Great care has to be taken to purify the thoria and ceria from other rare elements Further, the mantle is strengthened by being dipped into a solution of the oxides of aluminum and of the rare substance beryllium, and sometimes the name of the manufacturer is written on the burner with a solution of uranium nitrate Professor R. K. Duncan, writing in 1907, says: "In Germany alone over 150,000,000 gas-mantles are manufactured every year, and the total number manufactured the world over staggers belief. To manufacture these German mantles over 330,000 pounds of thorium nitrate are employed, 120,000 of which come from Brazil through the hands of a single firm at Hamburg Millions of money and thousands of men are employed in the utilization of a rare mineral which, a few years ago, had nothing but an academic importance."

The rare oxide yttria is used in conjunction with the rare oxide zirconia in the Nernst lamp, the only incandescent electric lamp that burns in air. This lamp gives fifty per cent greater light per unit of electrical power than the ordinary carbon filament lamp. It is interesting to note that cirium and yttrium are plentiful in the sun, and no doubt contribute to its radiancy.

In the Welsbach electric lamp the filament is made of the very rare element osmium. Osmium is a metal more than twenty-two times as heavy as water, resistant to all acids, and fusible only at a very high temperature.

Another rare metal, tantalum, is used as filament in other electric light lamps. Tantalum is an extremely rare metal, found in very few localities. Like osmium, it is very resistant and has a high melting point. In a slightly alloyed specimen it was found impossible to pierce with a diamond drill a sheet one-twenty-fifth of an inch thick, even though the drill was operated for three whole days at the rate of 5000 revolutions per minute. Even when quite pure it is as hard as the hardest steel; it does not rust; and it can be melted only at 2300° C. It can be drawn out into such fine wire that though twenty inches of wire are required for each lamp, a single pound of tantalum is enough for the making of twenty thousand lamps.

The most commonly used filament for the incandescent lamp at the present time is made from the metal tungsten, an element of not very common occurrence. These tungsten, or "Mazda" lamps, have been introduced and brought to a high state of efficiency by the General Electric Company.



A PIECE OF PITCHBLENDE, THE SOURCE OF RADIUM

Some of the rarer elements are also found useful in the preparation of alloys. Thus, steel can be quite altered in its properties by the addition of small quantities of vanadium, tungsten, chromium, molybdenum, nickel or titanium. Even the sluggish, inert gases of the air may at least perform æsthetic functions, since it seems probable that incandescent krypton produces the green light of the aurora borealis.

He would be a rash man indeed who would dare to assert that any of the elements are useless in the economy of man and nature, or that even now all the most wonderful metals have been found. The careful and very delicate methods of modern analysis have revealed in plant and animal tissues the unexpected presence, in small amounts, it is true, of compounds of copper, zinc and aluminum. Out of the elements common and rare are woven all the compound bodies of the world — the flesh of animals, the tissues of vegetables, the water of the sea, ooze of the sea-floor.

One of the most essential properties of matter is mass, measured by weight, and this results from the mutual attraction between all material substances. This attracting force, between the earth and all bodies on and near it, we call "gravity", the mutual attractive force between all bodies, even at great distances, we call "gravitation". It is gravity that holds the world together, it is gravitation that makes the tides, it is gravitation that holds the moon to the earth, it is gravitation that holds the earth to the sun, and keeps the stars in their courses. If we take a certain mass of an element we can melt it or vaporize it or freeze it, we can change its color and its shape and its consistency, but we cannot change its weight. The mass of a pound of water remains unchanged, though we freeze it into ice or vaporize it into gas. Chemists, accordingly, soon began to examine the weight of elements and compounds.

They found that some are light, like hydrogen, and some heavy, like lead, but they found out a more interesting fact still — that the elements which combine chemically always do so in definite weights and if more than one compound be formed by two elements, the varying amounts of one which combine with a fixed amount of the other, are always in the ratio of whole numbers, usually small. Thus sixteen parts by weight of oxygen combine with two parts by weight of hydrogen to form

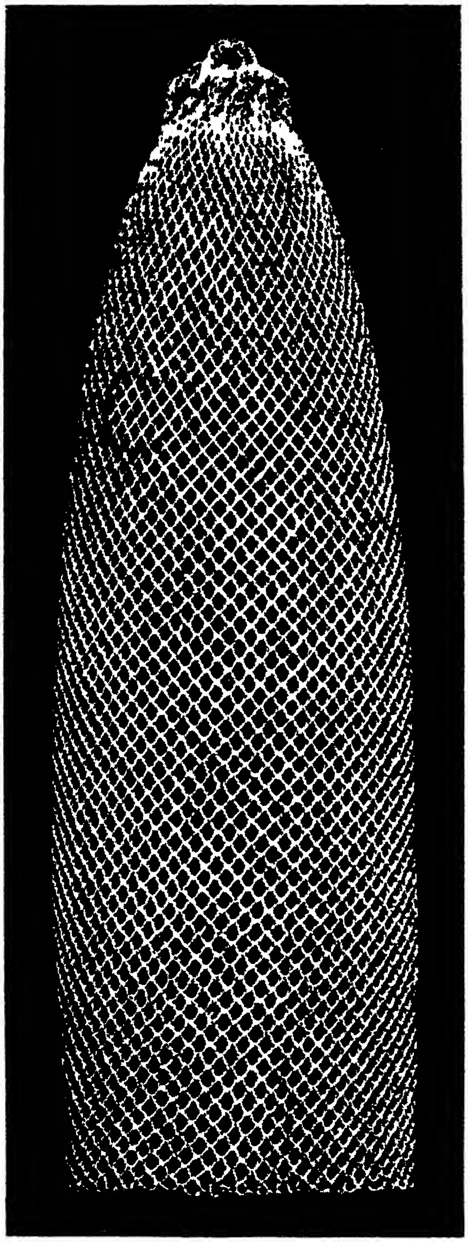
WEIGHING A GRAIN IN A MILLION PARTS

THE MARVELOUS SCALES WHICH WILL WEIGH THE MILLIONTH OF A GRAM OF RADIUM

A GUILLOTINE WHICH WILL CUT A 25,000TH PART OF AN INCH

By vaporizing matter at a high temperature and analyzing its light, the most minute traces of an element may be detected. A millionth part of a gram of calcium can be traced, and even one 180-millionth part of a gram of sodium. The sensitive balance is a precision instrument now for the chemist and the microtome, slicing extraordinarily thin sections of plant and animal tissues, is of inestimable value to the biologist and pathologist.

water, again thirty-two weight parts of oxygen unite with two weight parts of hydrogen to produce hydrogen peroxide.



A RARE ELEMENT THAT HAS COME INTO UNIVERSAL USE

It is often asked what purpose the rare and little-known elements can serve, and it is true that for many elements no use has yet been found But it is equally true that an element known only to scientists a few years ago as a thing of academic interest has now become the basis of an enormous industry Out of some of the rarest elements in nature are made the hundreds of millions of incandescent gas-mantles now used throughout the world.

Carbon unites with oxygen to form at least two different definite compounds. The first, carbon monoxide, an extremely poisonous gas, nowadays well known as the fatal element in the exhaust gases from automobile engines, contains three weight parts of carbon and four of oxygen; the second, carbon dioxide, usually and popularly called carbonic acid gas, is formed by the union of three weight parts of carbon and eight weight parts of oxygen.

Why should this be? Why should elements have these exact combining weights? Why should not hydrogen and oxygen equally well combine in irregular amounts by weight?

John Dalton answered this question by reviving the atomic theory of the composition of bodies He said that the elements could combine only in the proportions of their relative weights, or in some multiple of these, because all the elements were divided into particles that had certain definite weights, and could not be subdivided Assuming this — assuming that compounds must unite particle by particle — it necessarily follows that the relative weights of the particles must determine the relative weights of the elements in any compound The essence of the theory is that the ultimate particles of matter are of definite weight and indivisible, and that each element has its own particular particles or atoms, with a particular weight or atomic weight

Suppose one elemental atom weighs one grain, and another twelve grains Then they may unite in proportions one and twelve by weight, or two and twelve, or one and twenty-four, or two and twenty-four, or four and twelve, or in any proportions that are multiples of their atomic weights, but they cannot unite in such proportions as one and seven, since that would obviously involve the subdivision of a twelve-grain atom into seven and five The very fact that such irregularities in the combining weights of elements never occur seems to prove that their ultimate particles are really indivisible, as far as chemical means can go, and of definite weight. The weight of the atom of the element fixes the properties of the element.

The idea that matter is built up of ultimate indivisible particles is a very old one, having been first formulated by the Greek philosopher Democritus, and we find Sir Isaac Newton propounding it in no uncertain words. "It seems probable to me," he writes, "that God in the beginning formed matter in solid masses, hard, impenetrable, movable particles of such sizes and figures, and with such other properties, and in such proportion, as most conduced to the end for which He formed them; and that these primitive particles, being solids, are incomparably harder than any porous bodies compounded by them, even so very hard as never to wear or to break in pieces, no ordinary power being able to divide what God Himself made one in the first creation"

Dalton, of course, was not the author of the atomic theory, but he applied it to explain the facts of chemical combination; and though modern science is now reasonably sure of decomposition or decay of some elements, it will never cease to find the atomic theory a most useful working hypothesis.

DMITRI IVANOVITCH MENDELÉEFF

Though the elements have each individual weights and individual characters, yet some of them have resemblances to each other; and a German chemist, J. W. Döbereiner, showed that some of them could be arranged in threes or triads, so that each triad should contain elements noticeably like each other

But much more remarkable groupings of the elements were yet to be found. Professor Mendeléeff and other authorities have shown that if the elements, beginning with lithium, be arranged in series according to their atomic weight, every element tends to repeat, in increasing or decreasing degree, the properties of any other element eight removed from it. Thus the first and the eighth and the sixteenth have remarkable similarities; so have the third, the tenth, and the seventeenth; and so on.

If we simply arrange the elements serially, according to their atomic weights, in horizontal lines of seven with some regularly occurring variations we obtain perpendicular rows of related elements.

Each of the groups in such a table contains members with strong family resemblances to each other, and as we run up and down them, the particular family features either progressively wax or progressively wane; and if we know the physical and chemical characters of any one, we can tell pretty exactly the physical and chemical characters of its neighbors. Mendeléeff's condensed generalization of these relationships is known as the "periodic law," which may be worded in this way: the properties of the elements are periodic functions of their atomic weights, that is, as the atomic weights increase *or* decrease the numerically measurable properties of the elements increase *and* decrease.

As Professor Duncan well says: "The periodic law of the atoms is God's alphabet of the universe. By means of it alone can we ever hope to spell out the history of the future of creation. It lies before us, lacking only the master-word — the open sesame — to creation; and, who knows, to the Creator, too?"

To illustrate the efficacy of the law we need point only to its prophetic value in the hands of Mendeléeff. When he first made his table scandium, gallium and germanium were unknown, and in order to bring his grouping right he had to put blank spaces where these elements are now placed. But he was sure that elements there must be to fill these blanks; and from the situation of the blanks in the scheme he was able to predict almost the precise properties the missing elements must possess. In time the elements were found — "out of the night of the unknown, one after another came to meet him, one from the hills of Scandinavia, another from

the Pyrenees of France, and a third from the mines of Germany," and they were found to answer almost exactly to his predictions.

Surely a law with such amazing prophetic power — able to foretell the properties of an element unknown by man since the beginning of the world — must be based on a firm foundation However, like many other generalizations which seemed simple, clear and perfect in the beginning and then became a little cloudy as knowledge grew, so this law also has some difficulties of its own

Let us now look for a moment at molecules Atoms seldom, even in simple gases, at moderate temperatures, remain single, they always tend to join and form complexes known as molecules. The basis of all compounds — and there are hundreds and thousands of compounds in the world — is the molecule formed by the junction of atoms In most inorganic compounds the atoms that make the molecule, and by their conjunction produce all the properties of the compounds, are usually few in number Thus the molecule of water consists of two atoms of hydrogen and one atom of oxygen; that of sulphuric acid consists of two atoms of hydrogen, one of sulphur, and four of oxygen; and that of carbon monoxide consists of one atom of carbon and one of oxygen On the other hand, the molecules of organic substances, and of the so-called "carbon compounds," are often composed of a multitude of atoms. Thus, the molecule of blood-albumin or serum-albumin is (somewhat doubtfully) supposed to contain 450 atoms of carbon, 720 atoms of hydrogen, 116 atoms of nitrogen, 140 atoms of oxygen, and 76 atoms of sulphur; while the chemical composition of nuclein is still more complicated, nuclein being a complex albuminoid substance containing also phosphorus and iron in organic combination In many cases the molecules in the carbon compounds are probably built together in bits, so to speak, and their architecture is indicated by names such as "tri-phenyl-triamido-di-phenyl-tolyl-carbinol," and "hexa-phenyl-iso-propyl-methyl-ketone-carboxylic acid."

How synthetic chemistry has built up many compounds unknown to nature

The science of chemistry consists mainly in a knowledge of the different affinities of atoms, and of ways in which molecules can be broken down and built up, and the science of modern synthetic chemistry has succeeded in building up some thousands of interesting compounds that are quite unknown in nature.

It is a curious thing that the social proclivities or combining tendencies of atoms vary immensely, some — such as argon and fluorine — being very averse to combination, and others — such as carbon, oxygen, nitrogen and hydrogen — being willing to combine in an infinite variety of ways The force of affinity also varies in a very interesting way. Potassium is so fond of oxygen that if a little piece of potassium be laid on the surface of water it will rush about, tearing up the molecules to obtain oxygen, holding all the oxygen and part of the hydrogen and acting with such fervor that it sets fire to the hydrogen it frees. Hæmoglobin, again, seizes oxygen readily, but does not retain it very firmly, otherwise we should all be in a sorry, cyanosed condition. Fluorine, again, will not have oxygen at all, but rushes to hydrogen with explosive violence.

Where the mystery of the architecture of a myriad of compounds lies

Even more interesting and wonderful than chemical affinity itself are the results produced by the combination. The two gases oxygen and hydrogen join, and behold we have the wonderful liquid water. The metal gold and the corrosive vapor chlorine join together, and lo! we have a reddish brown solid very soluble in water. The carbon of a diamond and the oxygen of the air join, and lo! we have a suffocating gas. The gases oxygen, nitrogen and hydrogen join with a little carbon, and sulphur and phosphorus to form, under the guidance of the vital principle, a seed that grows to a man. In the affinity of a few elements lies the mystery of the architecture of a myriad of compounds — each a chemical palace.

WOMAN—MOTHER OF THE RACE TO BE

MADAME LE BRUN'S BEAUTIFUL PICTURE OF MOTHER AND CHILD, NOW IN THE LOUVRE

THE MYSTERY OF SEX

The Great Antiquity of Sex and Its Real Purpose in Life

CARRYING ON THE LIFE OF THE WORLD

IN the history of life, in so far as we can obtain any notion whatever of what that history has been from a study of the life processes and activities of the various types of living organisms of today, it seems clear that what we have called asexual reproduction preceded the sexual method in the progress of development. Let it be understood here once and for all that the significance, the very essence, of sexual reproduction lies in the fusion of two distinct cells, called gametes, to form a zygote for the purpose of propagating the species and not in the fact that these two cells may have chanced to spring from the bodies of two different individuals of the same species so specialized and differentiated that we have designated them as male and female.

In other words, development in individuals of what is termed sex has been a *result* of the development of this mode of reproduction, not the cause of it. Many of the lower forms of life in which there is no apparent sexual differentiation whatever, reproduce by the formation and fusion of gametes just as in the higher forms. Furthermore, in an animal as high up in the scale of life as the common earthworm, in which reproduction is exclusively sexual, there is no differentiation of sex among the individuals, for each individual worm possesses both male and female sex organs and consequently produces both eggs and sperms. Hence the evolution and maintenance of sex, whatever it means, is most certainly not for the purposes of the sexually differentiated individuals, male and female, but it is definitely for the purpose of sexual reproduction, and thus for the race and the future.

What the advantages of sexual reproduction are, for which sex exists, we must in due course endeavor to discover. It is certain that they exist; and recent work has proved, once and for all, that the greatest of its functions, that of providing new variations and making progress possible, is indeed discharged by it, notwithstanding the confident verdict of one school of workers to the effect that variation in the offspring exists as much under asexual as under sexual reproduction.

If we are to estimate, in the first place, the importance and the vital depth of our subject, we must observe how widely and consistently the fact of sex manifests itself. Having observed the simple one-celled animals and plants, such as amœba, certain algæ and bacteria, we saw that they were sexless, though it remains as we have stated above that some of the one-celled forms have been observed to pair in a fashion which is truly sexual, though those creatures exhibit no sex-differences to the closest observation. If now we pass higher up the scale, whether of animals or of plants, we soon encounter obvious and typical sex, and are clearly taught that life has deliberately and consistently shown itself in sexual form, male or female, throughout all its stages, from a very remote time.

But until very recent years no one suspected how far down in the scale sexual reproduction was to be found. When we are dealing with creatures of the amœba pattern, which consist of only one cell, and which have no *body* to display differences of sex, as the bodies of higher organisms do, we do not find it credible that sex should yet have come into being.

Not long ago any biologist would have said that, before we can discern sex, we must at least reach the stage of the many-celled creatures. As these evolved we should find that they show themselves in two forms, male and female, according to the contrasted type of their bodies, and of the germ-cells which they produce — or which are produced in them. But sex in one-celled creatures — never!

The present writer well remembers the incredulity with which he read the first accounts of the changes in form and the life-history of the malaria parasite — a minute, one-celled animal organism found in the bodies of certain mosquitoes, and in the blood of men suffering from malaria. Observers declared that there were stages in the life of this creature when two contrasted types of cell were to be found, and these contrasted types, as their form and behavior showed, were male and female. However, actual observation must convince the most incredulous that the facts are so, for they can be directly observed under the microscope and must be accepted. We now know that there are many kinds, no one yet knows how many, of one-celled organisms which reproduce sexually; and we have to realize that sex is thus vastly older and far more deeply rooted in the very nature and necessities of life than we had ever supposed. These new discoveries in the realm of the microscopic and most humble forms of life thus increase our estimate of the importance of sexual reproduction and its function in the living world.

There is, however, another question which we must answer before we are content to infer the importance of sex from its antiquity and long persistence in the history of life. It is a question which primarily concerns the biologist and student of evolution, and which he must answer on the evidence, without a thought of any other interest.

But the answer to this question involves us at once in the very thick of the most controversial and angry of political arguments, for it obviously involves the character and destiny of womanhood and its functions in human society.

The question is this. If sex is a very ancient attribute of life, and is found among very humble and insignificant species, may we not find that the true course of evolution has been, is, and must be to control, narrow down, and even substantially obliterate sex-differences? The very argument as to the importance of sex, which is derived from its newly realized antiquity, is also an argument, or may be made one, in favor of the view that, as life ascends, sex ought to become less important — that women should compete with men in every sphere of human existence and activity.

Our business here is to do justice to the scientific truth, and on no account to let it be mixed up by passions and prejudices of men and women, and least of all by sex-antagonism, which works foul mischief in human life equally when directed by men against women or by women against men.

Also, the man of science, in stating the facts as he sees them, requires to protect himself and them from those who proceed to argue therefrom, on any side. It is necessary to argue from scientific facts. The man of science declares, indeed, that nothing is true or durable or ultimately useful, in individual or national life, which is not based upon sound argument from nature. But he finds that he no sooner states a fact than people seize upon it for their own purposes, and often assert conclusions therefrom which the man of science knows to be dubious or even false. Here, therefore, the facts of the evolution of sex are stated, as is our present duty, and all conclusions based thereon by all persons who have already made up their minds are disclaimed as without warrant in science.

The contrast between the sexes is most marked among insects, where the rule is that the males are smaller, weaker, shorter-lived, and grossly inferior in instincts, as bees, ants and wasps, to take the most celebrated cases, abundantly illustrate. It is true that sex-differences among vertebrates are not so great as among the insects, and it has hence been argued that sex-differences are diminishing as life ascends. This is to assume, together with many other arguable points, that vertebrates are descended from insects.

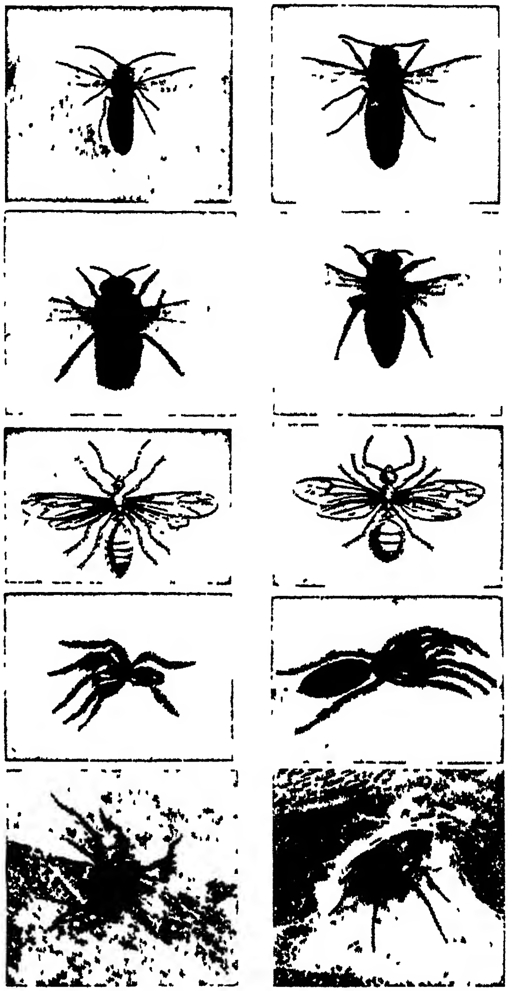
That was not the case. The insects and their evolution are peculiar, apart, notable and admirable indeed, but incapable of proving what many attempt to prove, though they do illustrate truths of general import We do not know where the insects are going, nor what they are after

We do know, however, that in a host of respects their capacities, and especially their social and racial life and organization, are vastly superior to ours, and the argument from the insects may very well be, in reality, that if we are to attain a higher, less wasteful, more admirable civilization, we must have not less, but more, differentiation between the sexes, for there can be no doubt that the achievements of insect civilization entirely depend upon, and involve a far greater measure of, sexual differentiation than anything to be found among the vertebrates Observing, then, that the argument from the insects cuts both ways, and requires more analysis if it is to serve the cause of truth, we may leave them on one side, and proceed to the evolution of sex in the line of progress, at the extremity of which stands man.

The evidence is clear — much more so now than even twenty-five years ago — that the open road of life has been taken by forms in which sex has been progressively more, and not less, important In short, sex is an early instrument of life, early because essential, and the instrument becomes more powerful, more delicate, more subtle in its work, and ever more absolutely essential to the advance of life, as life advances. This is the evidence afforded by a survey of living forms in general, not animal only, but also vegetable; and it emphasizes the importance of sex, with all the force of immeasurable experience, against those who say that the trend of evolution is towards the obliteration of sex-difference.

In the judgment of those who have thought longest and most seriously on this question, the demands of further evolution require not less differentiation of sex, but a juster appreciation, by men and women alike, of the natural indispensable difference between them, ineradicable save at the cost of the race itself.

It were well to return quickly from these questions of interpretation to the facts, but the facts could not be appreciated until we had definitely satisfied ourselves of the importance of sexual reproduction as proved by its almost incredible antiquity, very nearly coeval with life itself, by



THE SEXES AMONG INSECTS AND SPIDERS

In insects the contrast between the sexes is usually most marked, the general rule being that the males are smaller, weaker, shortlived, and grossly inferior in instincts. These pictures show both sexes of the wasp, the bee, the ant, and two kinds of spiders, the female in each case being on the right.

its persistence, its constant exhibition in vegetable and animal life alike, its conspicuous development, and evidently indispensable function, in the highest achievements of life which have yet been discovered — the societies of insects and the societies of man.

It has already been argued that sex exists for the purposes and the advantages, still awaiting complete discovery, of sexual, as distinguished from asexual, reproduction. Before we study the essential facts of that process, we should endeavor, by a survey of male and female forms, as the world of life displays them, to state what essential difference it has brought about between the sexes. It needs little looking to show that the difference is not one of size or color, or intelligence or muscularity, or external form, or any other of those things which most readily occur to us. These differences exist, but there is no constancy in them, for sometimes the male, sometimes the female, may have the advantage. The essential difference lies deeper, and we owe its first adequate recognition to the two distinguished Scotchmen, Professor Patrick Geddes and Professor J. A. Thomson, whose book on the "Evolution of Sex" has established the matter once and for all. They showed the essential difference between the sexes to be that the female spends a less proportion of energy in the present and for herself, as compared with the proportion she stores up for the future of the race; while the male keeps and devotes less of his vital powers to the future of the race, and spends more upon the present.

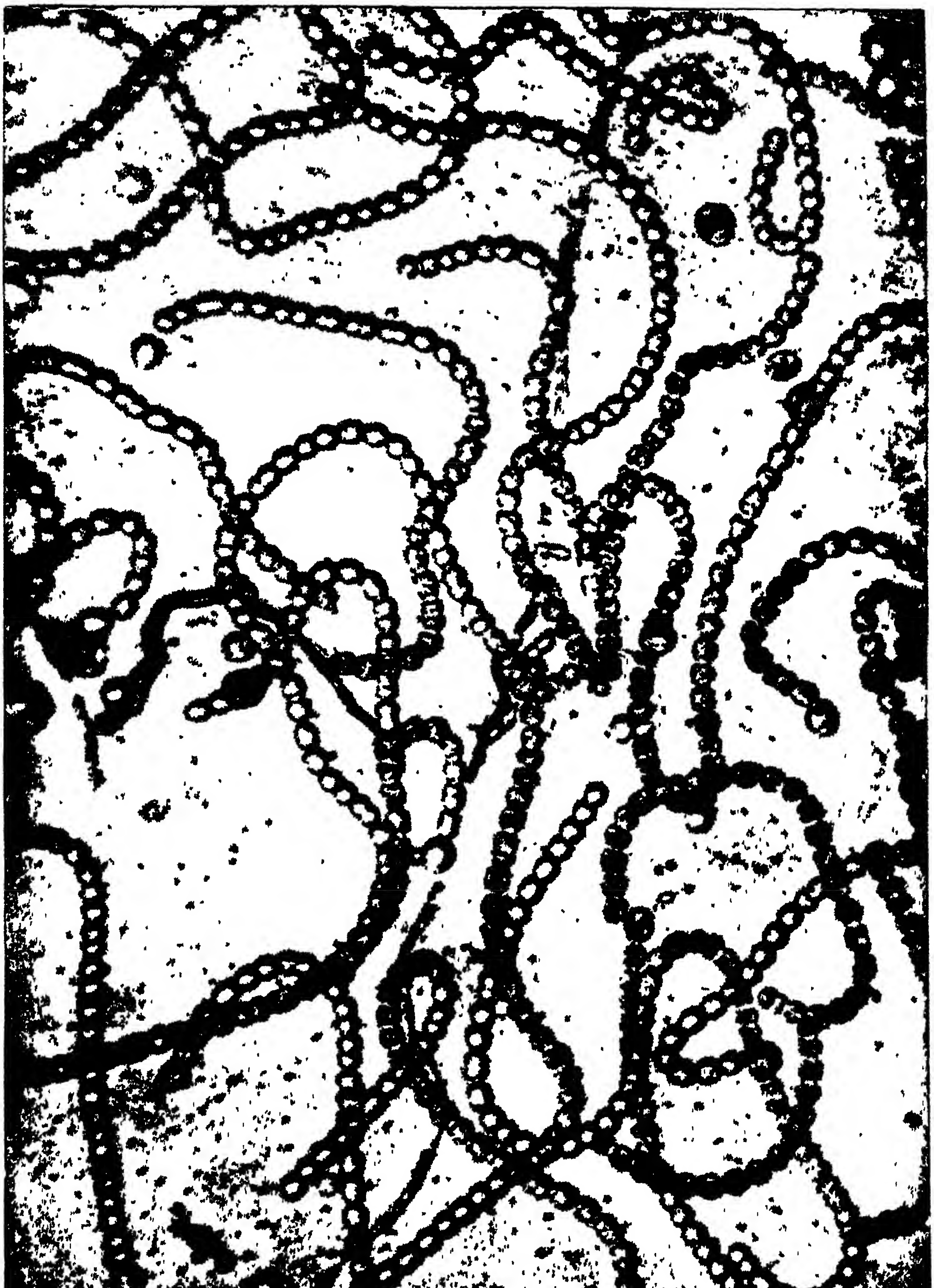
Every living individual has a certain amount of energy to use. If the law of the conservation of energy means anything, and if it applies to living beings, as it assuredly does, it means that they must in every case make some adjustment between what they spend upon themselves and what they keep to spend upon the future. The physicists teach us to think of energy as either *potential* and stored up, or *kinetic* and in action. Now, the essential and necessary difference between the female organism and the male organism is that, though both have themselves to maintain by present action and expenditure, and though they have the future to contribute to and provide for, by storing up energy, and not spending it, the ratio of expenditure to thrift is higher in the male and lower in the female. The male spends, moves, seeks, destroys, invents, obtains. The female saves, stays at home, is patient, constructs, rejects, maintains. He is the innovator, the liberal, she the maintainer, the conservative. The theme is a great one; but our present business requires the noting of only one further point.

It is that these essential and general differences of sex, clearly displayed by normal and typical members of either sex in any species, are also displayed by the germ-cells which it is the essential business of the individual organism to produce and protect for the supreme need of reproduction and race maintenance. When we come to study Weismann's work we shall see that, in a special and limited sense, germ-cells are perhaps not produced by, though produced in, individuals. Meanwhile we may speak in the ordinary language.

Observe that the difference between the sexes, as defined above, is no more than a matter of proportion — that the ratio of self-preserving to race-preserving expenditure is, on the average and typically, higher in the male organism than in the female. But obviously we require also a clear understanding of what it is that makes any given organism male or female respectively. The answer is positive and fundamental. A male organism produces one kind of germ-cell, and a female organism produces another kind. Whatever organism produces male germ-cells is a male, whatever produces female germ-cells is a female. Again, the great principle is found to be true — that by the fruit shall the tree be known.

Now, the point we require to observe is that the difference between male and female organisms, already defined, is shared by their respective fruit, the germ-cells. The rule, which we find equally and indifferently illustrated in the case of the highest species and the lowest, animal or vegetable, is that the male germ-cell is active, mobile, and usually smaller; while the female germ-cell is passive, stationary, and usually larger, because it usually has associated with it a lesser or greater quantity of stored-up energy, in the form of food for the young life that is to be. This we see in the bird's egg, and in a thousand other cases.

A CHAIN OF LIVING PLANT-CELLS



All the higher forms of plant life are many-celled organisms, the unicellular—or one-celled—animals or plants being quite the lowest in nature's scale. The fresh-water alga, shown magnified 50,000 times in this photograph by Mr. J. J. Ward, is a specimen of plant body made up of simple cells joined together.

However, we do much less than justice to the principle discovered and elucidated by Geddes and Thomson unless we complete the argument by recognizing that the great, the only unquestionable and cardinal, difference between the two sexes is to be found not so much in the bodies and behavior of individuals of the two sexes respectively, as in the nature and behavior of the germ-cells which those bodies produce.

We must beware of a most excusable confusion which is almost general When we talk, as we do, and as science will ever increasingly do, of male and female germ-cells, we must understand that we are referring to the parent, the organism that produced them, not to the organism which they will produce A female germ-cell is so called because it has certain characteristics, which are also to be found in the individual that produced it. But this germ-cell might well contain maleness, for it may when combined with another germ-cell become a male individual. Mothers have sons, we all know; and if we think about it at all — which is very improbable — we probably suppose that the maleness of the son is derived from his father, and the femaleness of a daughter from her mother. The case of any species which shows "alternation of generations" disproves this, for there we find offspring of both sexes being produced by an individual which is itself without sex, and the production of drones by the unfertilized eggs of the queen bee is conclusive.

In this remarkable case, which upsets all our preconceptions, and gives us entirely new and lasting conceptions instead, we find that the female germ-cells produce males so long as they do all the work alone, but that if the female germ-cells be fused with male germ-cells, the resulting individuals are female! We ought therefore to know what we mean, and what we do not mean, when we speak of male and female germ-cells, and we are to be prepared to find a female germ-cell carrying the quality of maleness for the individual which is to be formed therefrom, or a male germ-cell carrying the quality of femaleness.

The confusion of language is unfortunate, for it seems absurd to speak of that as a female germ-cell which is indeed none other than an immature male individual. We should say, not "female germ-cell" or "male germ-cell," but "germ-cell from a female (or a male) organism" — or, more appropriately, "ovum" or "sperm"

And now we come to the central, essential, mysterious, creative fact of all sex, which is that sex exists for sexual reproduction, which consists in the fusion of two germ-cells, ovum and sperm, in such a way that they become a single cell, which is the new individual, and may itself be of either sex. The oak, the whale, the lobster, each is at first a single cell, thus formed, and so also is the body of man.

The supreme, creative act of cell-union is effected by the fusion of the two nuclei, which are the essential parts of the germ-cells — "gametes" (marrying cells), we should now call them. But these gametes, of course, do not unite until they are mature; and their union will be unintelligible to us until we look at the process which has been known for many years as the "maturation of the germ-cells," and is now known as "gameto-genesis."

Within the details of this process the facts and methods of heredity are hidden, and now, indeed, partly revealed; and that is the best of reasons why we should understand their nature as soon as possible.

The body of an individual, male or female, of any typical species of animal does not contain an indefinite number of ripe or mature germ-cells, but a number of cells, which taken together constitute the germinal epithelium whose function it is to give rise to cells that in the end produce gametes fit for union This is gametogenesis, and it is a most complicated and elaborate process of cell-growth and cell-division, which is being gone through continuously by the reproductive tissues of all the higher animals.

But the essential phenomena of gametogenesis are to be observed only through the microscope, and they are unmistakable and purposive almost beyond vital processes in general—which is, indeed, saying a good deal.

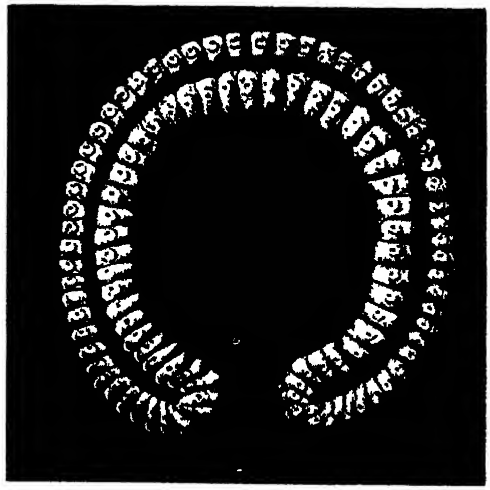
What we find in both sexes alike is essentially this: cells in the germinal epithelium — found in the reproductive organs of animals — divide and divide again, until one final division, which is different from all preceding it, and, indeed, from all other processes of cell-division found elsewhere. The peculiarity of this last division of the "mother-cells," as they are called, of the gametes, is that the chromosomes are not split and divided among the daughters, as in all other cases.

The very last cell-division, the result of which is the final gamete, ovum or sperm, as the case may be, ignores the ordinary rule, and involves an allotment of the chromosomes of the nucleus among the daughter nuclei, so that each daughter nucleus gets half of the number of the chromosomes in the parent Suppose, thus, that twenty-four is the normal number of chromosomes formed in the dividing nucleus of any cell of the body in the species in question We know that, when ordinary division occurs, and new cells are formed, each chromosome of the dividing cell is split into two equal parts, one of which passes to one of the new cells and the other to the other, so that the new cells have as many as their parent.

But in the final division of the cells in the reproductive tissue — the division which gives rise to the gametes themselves — the chromosomes are distributed, so that each final or "ripe" or "mature" germ-cell has one half the number of chromosomes proper to the species. In the case in question, therefore, each gamete, whether formed in the male or in the female body, has only twelve chromosomes composing the chromatin of its nucleus, instead of twenty-four. And, so far as we can judge, the whole amazing process of gametogenesis, or germ-cell formation, as we see it in the reproductive organs of animals, exists above all to effect this remarkable "reduction of the chromosomes."

Whenever, then, we examine a germ-cell or gamete, of any individual of any species in which the number of chromosomes is the same in both sexes, and find that its nuclear chromatin consists of, say, twelve chromosomes, we shall not declare that twelve is the characteristic number for the species in question, for we shall find twenty-four in all the cells of its body but these. Several of the numbers formerly stated to be characteristic of the corresponding species require to be doubled, as they are the numbers found in the germ-cells, in which the "reduction of the chromosomes" has halved their number.

It need hardly be said that the object of this reduction is to produce a nucleus, male or female, so constituted that it requires the addition of another similar nucleus, female or male, to make it complete, after the fashion of the species to which it belongs The new nucleus has its complement of chromosomes; and its division, and the innumerable divisions of its descendants, to make the body of the new individual, are conducted so as to maintain this number throughout the entire process.



THE BEGINNING OF LIVING STRUCTURE

Cell division, as shown on page 617, builds up new life, cell combination builds up structure Countless billions of cells arise in the body of a living thing, joining together to form its various parts This picture represents cells in a section of an embryonic animal form

Within the last few years the discovery has been made that these rules are not observed in the case of the disease called cancer, which consists of an abnormal cell-growth in the body. There is evidence to show that the process of karyokinesis in the cells of a cancer is wholly unlike that of normal body-cells, and is more allied to the type of nuclear division which we see in the formation of germ-cells.

Students of cancer are agreed that this fact is fundamental, and are now using it, with definitely approaching success, as a clue in the search for the causes which lead cells of the body to behave not as cells of the body should, but rather like cells of a new and alien generation. This is not the place to discuss the subject further, but the facts are profoundly instructive in teaching the unity of science amid all its multiplicity, and the fashion in which remote lines of research are bound together.

The gametes, male and female, now unite. The circumstances are infinitely various, but the essential fact is one and the same whether we study fertilization in a plant, the shedding of the ova of a fish and their fertilization in the water, or the various means by which the gametes are united to form one cell, in the case of the higher animals, and many of the lower animals too. It is sufficient to note that, in every species where the mother sustains the new life within her own body, and above all in the case of the mammalia — the best representatives of the animals which bring forth their young alive — the fusion of male and female gametes occurs within the body of the mother, where the development of the new being can take place in the greatest certainty and most assured safety.

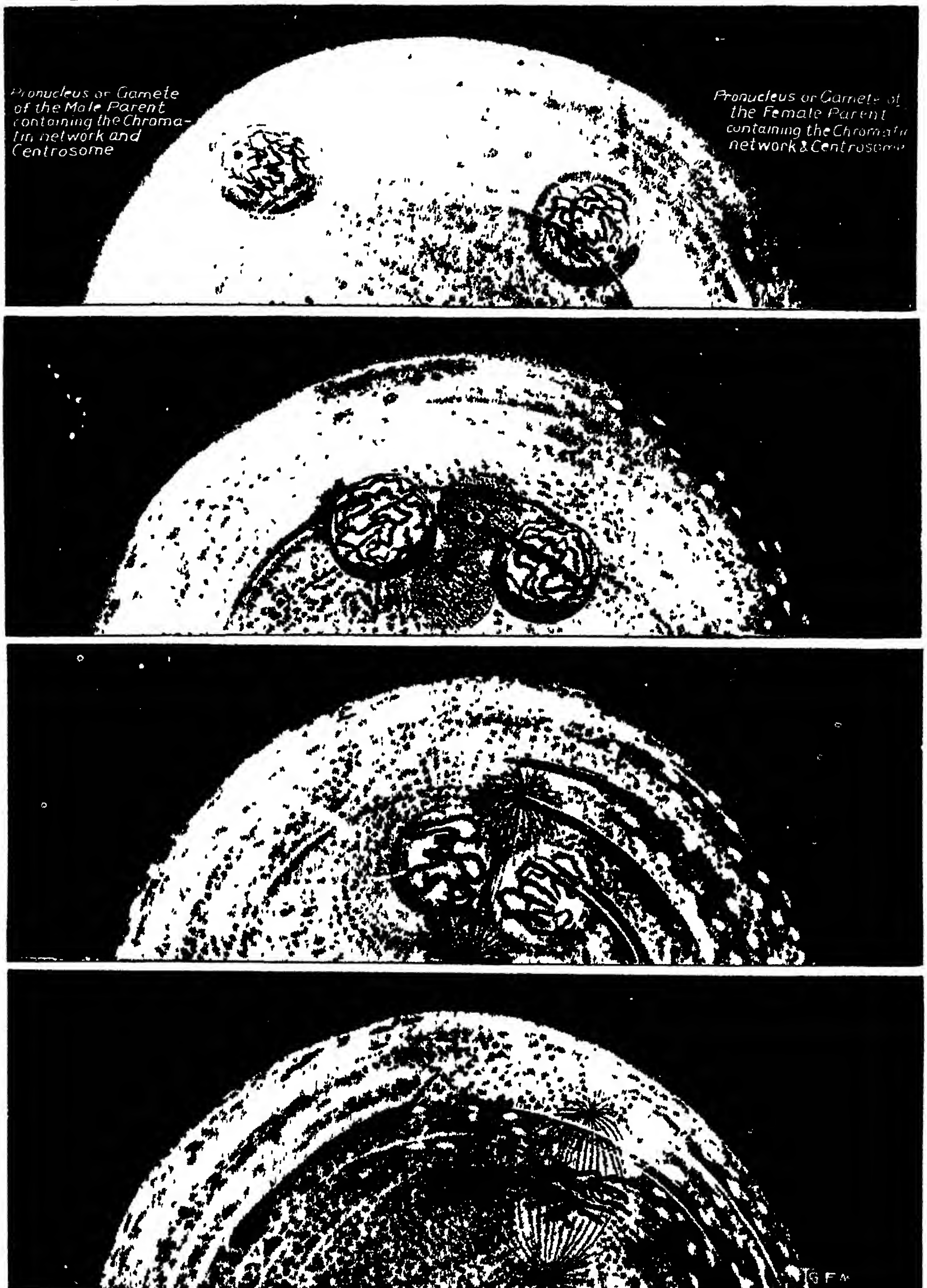
The essential fact in all cases is not the conditions or circumstances of the cell-union, but the fact that it occurs, and that the fusion of the nuclei is of the most perfect and intimate character. The new being, formed by this yoking, or pairing, is called the "zygote" (*i e* the *yoked*) and all our studies up to this point find their conclusion in the fact that the zygote, as represented by the single cell from which all the development of the future springs, is a cell whose nucleus is equally constituted of the nucleus derived from its father and also from the nucleus derived from its mother.

That is what is the meaning of the whole process. No sex-antagonism, no vaunting of one sex over the other, is here; no warrant for anything but sex-harmony, coöperation and equality. The new nucleus is constructed equally from paternal and maternal material, and although they seem to fuse and to mingle intimately in the resultant network of chromatin, nevertheless do not lose their individuality.

The chromatic network of the new nucleus is thus, though single, yet double; it is of double origin, for paternal and maternal substance are yoked in every portion of it. When it divides, which it does in the fashion now familiar to us, its chromosomes, as they split, carry paternal and maternal substance to each daughter cell, and so on to the end. Every skin-cell of the myriads which we shed every time we wash our hands contains a nucleus of which one half was derived from our mothers and the other half from our fathers. A generation ago Huxley said: "It is conceivable, and indeed probable, that every part of the adult contains molecules derived both from the male and from the female parent, and that, regarded as a mass of molecules, the entire organism may be compared to a web, of which the warp is derived from the female and the woof from the male." To this most admirable speculation, now justified, Professor E B. Wilson adds the comment: "What has since been gained is the knowledge that this web is to be sought in the chromatic substance of the nuclei, and that the centrosome is the weaver of the loom"

Fertilization, or the process of making fertile, is the old and intelligible name for that which enables a new life to develop, but the earlier theories as to how this was accomplished were erroneous. The gardener and the agriculturist, the botanist and the student of heredity, long thought of the elements derived from the male organism as somehow making fertile the life which is latent but unrealized in the cell of the female organism. These cells in animals or plants we may call by the old name of "ova" or eggs, and we assume that the ovum waits for the coming of the sperm produced by the pollen in the case of the plant, or of the spermatozoon in the case of the animal, to make it fertile. The implied idea is that the male influence is a fertilizing, stimulating one, but that the mother is the real parent.

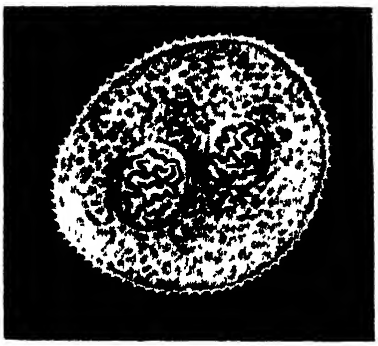
THE BIRTH OF PLANT AND ANIMAL LIFE



These pictures represent the astonishing process by which is produced the first complete cell of plant or animal life Shown here largely magnified, these cells are actually invisible specks, yet holding within themselves all the potentiality of life, all the characteristics of the individual, with its infinity of variations In the top picture the cells are seen approaching each other, and, as they come together, the centrosomes of the two cells leave the cells, and, as shown in the second picture, begin to develop the achromatin filament which ultimately links them, as in the third picture. The chromosomes attached to each filament now combine to form the first cell of a new organism, and the union of the two cells has thus created a power that neither had before — the power of building up a new individual. The new cell has also the power of reproducing itself, as shown on page 618, until the organism is completely built up

The contrary idea is scarcely less familiar in men's thinking on these matters. Arguing from the facts as they appear among the higher animals, for instance, men have argued that the father is the real parent — as the transmission of surnames in most human societies suggests — and that the mother is only the host, trustee, nurse, temple of the new life

The facts directly contradict both theories. Neither the mother nor the father alone is the real parent, as the above theories implied, the new nucleus is formed, with strict and most minutely detailed justice, of elements equally derived from both. So far as hereditary transmission is concerned they are absolutely equal. Yet it is worthy of note that, in most cases, the female gamete and the male gamete each bring with them something, for the service of the new life, beyond what actually goes to the constitution of the new body. As a rule, the female gamete brings with it a store of nutriment, which, in the case, for instance, of the bird's egg, may be amazing in bulk. This nutriment is not the gamete, but accompanies it. The vast majority of ova are more or less supplied with this store of energy; and we note the exact correspondence of the facts with the theory of Geddes and Thomson that the female sex stores and conserves, rather than spends.



A GERM CELL OF PLANT LIFE

A section across a pollen grain, showing the nuclei which start the fertilization of plant life

Just so do we find that the male gamete, or spermatozoön, brings with it something which is more than its nuclear chromosomes. It appears that, at any rate in many observed cases, the female gamete has lost its centrosome — that curious body which lies beside the nucleus of a typical cell, and starts its division. The ovum, or female gamete, to use the more definite term, has a nucleus, but no centrosome.

Now, the evidence available indicates that, among those species in which a centrosome is always present in the cell, the nucleus alone could not divide if it would, for the centrosome, we saw, is the initiator of nuclear division. When we study spermatozoa very carefully under the microscope, we find that, in a wide variety of species, they contain, in addition to the essential nucleus, a minute particle which is really a centrosome That centrosome of the male gamete becomes the centrosome of the new cell, formed by the union of male and female gametes. When the cell divides and proceeds to develop into the new individual, it is the centrosome, derived from the father, that starts the process, and keeps it going, inventing, stimulating, spending, moving; and it is the store of food brought by the female gamete that makes the first activity of the centrosome possible.

We see, then, how exactly — nay, how exquisitely — the functions of the two sexes are coordinated in the business of reproduction, and we realize, as never before, that every individual which has been formed by the process of sexual reproduction is a double being, formed of a part derived from each parent. The name of "zygote," which modern biologists have now agreed to use, exactly expresses this truth — that the new individual is twofold, made of two parts which are yoked to form one This statement in itself may seem of small importance, but when we attempt to unravel the facts of heredity we discover that this double character of every individual, one as an individual, but two from the point of view of ancestry and offspring, is the master-key to the problems of heredity, as Mendel taught an unlistening world from his monastery garden half a century ago.

Meanwhile we are confronted with the new nucleus, the single cell or zygote, which may, according to its potentiality. develop into an oak or a whale, or a new individual of any species; and in its tiny and well-nigh inscrutable countenance we try to read the incredible and miraculous story of development.

THE FERTILITY OF THE SOIL

How the Food Supply in Mother Earth's
Cupboard Is Replenished and Sustained

THE SCIENTIFIC CULTIVATION OF THE LAND

WE have already regarded the soil from several viewpoints. We have observed it in the making. We have seen the barren rock gradually decay into fertile soil. We have examined the forces which have effected this change and noted the kinds of soil which have resulted. We have viewed the soil particles under the microscope and discussed the properties which they impart. The water of the soil has not escaped our study nor have we yet ceased to wonder at the complexity of the life therein. All of these conditions make for a productive soil and the study of this productivity and its maintenance is called the "fertility of the land."

This phase must now receive attention.

The methods by which plants extract nutrients from the soil have a great deal to do with the ability of a soil to remain productive. Let us examine for a few minutes the mechanics of this process. We already know that the oxygen, hydrogen, and carbon of the plant come from the air or water. As air and water are for the most part abundant, the elements taken from the soil become a controlling factor and the object of our concern. How is the nitrogen, the phosphorus, and the potassium taken up? An understanding of this process will aid us in meeting the problem of maintaining indefinitely the productive capacity of any soil.

THE SOWER GOES FORTH TO SOW—FROM THE PICTURE BY F. E. MICHEL

The problems of soil fertility are as old as the civilization of man

Since plants are more or less fixed in one spot, unable to move about with the freedom of animals, the food in the immediate neighborhood must soon be exhausted. The roots, of course, can and do extend themselves but this is not enough. They cannot reach and touch every one of the billion of soil particles, nor can they come in contact with all of the immense surface exposed thereby. The plant must have a servant to carry the food to it from the intricate and secret points of preparation. We already know that water is this servant and how willing it is when it is present in sufficient amount. We also know that the food must be in solution before it can be carried to and taken up by the rootlets. The question we have not as yet discussed is, how do plants actually take up their food from the soil? Do they have mouths as we do? If not, what is nature's provision for them?

ABSORPTION HAIRS ON THE TIP OF A BARLEY ROOT

These root hairs appear just back of the root tip and control the intake of plant food

Plants consist of cells, each cell filled with protoplasm and inclosed by an envelope. It is necessary that all food must find its way through this envelope before it can be built up by and into the protoplasm within. This is a necessary conception which forces us to the view that these cell walls of the root hairs are so made that food particles can pass inward and that other materials cannot to any degree pass out.

The openings in the cell wall which allow this exchange are infinitely small but they must exist. The whole condition has been aptly compared to a fine sieve, the wall of the cell envelope corresponding to the network of the sieve. The process by which water passes from the soil through the cell wall into the plant is called "osmosis." Food materials enter by "diffusion." That is, using the water as a medium in which to move, the food can pass through the meshlike passages of the cell.

The fact that only a very limited portion of each rootlet, just back of the tip, possesses this absorbing power is a point to be kept in mind. We can, moreover, conceive that the protoplasm is able to some extent to select such foodstuffs as it may need and go on doing so until the requirements of the plant are satisfied.

The plant obtains food materials both through its leaves and through its rootlets. These two streams mingle within the plant, and by means of the energy obtained from the sunlight many sorts of complicated materials are built up, all contributing to the normal growth of the crop. Under the process starches, sugars, fats, oils, proteids, and so on making up a plant are manufactured from the simple constituents taken from the soil and the air.

Soil fertility

The soil is a great factory or laboratory for the manufacture of plant food. Those processes we have reviewed. The plant is equipped to avail itself of this food. The means thereof we understand. One question remains, can the soil be exhausted, if so, why? We must look back now to our first chapter. Here we found that the plant must have ten elements of food in order to grow. Three of these are likely to be either lacking or unavailable. If even one is not present in sufficient amount, it becomes a limiting factor, and until this deficiency is supplied the soil does not reach its full productivity. This is not the only danger. Other factors come in. Not only must there be plenty of available food present, but the physical condition of the soil must be favorable, the water content at or near its optimum, organic matter must be present, heat relations right, the soil sweet, and certain bacteria should not only be present but performing their normal functions.

From Montgomery's *Productive Farm Crops*, J B Lippincott Co

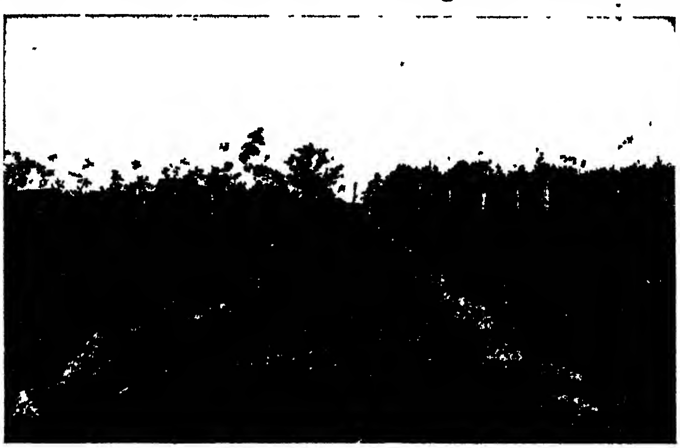
PLOWING UNDER A GREEN MANURE

By this means the organic matter of a soil may be very quickly increased.

The maintenance of soil fertility means a consideration of all of these several factors Any one of them if neglected will lower the crop-producing power of the soil Let us then consider some of the practices which the farmer makes use of in keeping up the store of food in the soil and in making available that which is already present

Green manures

History shows us that the turning under of green crops has long been an agricultural practice. The use of beans, vetches, and lupines were well understood by the Romans and probably by the nations that came before them. At the present time green manures are considered, in some form or other, a part of of every well-established system of soil and farm management



From Lyon's *Soils and Fertilizers*, The Macmillan Co

COVER CROPS IN VINEYARD

The use of cover crops in fruit production has proven to be a practical procedure. Such crops protect the soil at critical periods and serve in addition as a source of organic matter.

The green material should be plowed under when it is most succulent or moist. In this condition considerable water is added to the soil and the decay goes on rapidly. In turning the material under the furrow slice should not be thrown completely over, since the green crop is then

deposited as a layer between the upper and lower soil It may thus cut off water movement and injure the succeeding crop Generally a green manure should be followed by a cultivated crop The bacterial activities as well as air and water movement are stimulated by the tillage thus received. If the soil is the least bit acid, lime should be added before or with the green manure to counteract the products of the organic decay

The crops used for green manures differ according to the section of the country Rye, oats, and buckwheat are common non-legumes Rye and oats especially are of value, as they grow rapidly and their seed is not costly They do not have the power of fixing nitrogen as do the legumes and consequently only raise the store of organic matter without increasing the nitrogen They are very valuable, nevertheless Cowpeas, soy beans, vetch, crimson clover, and field peas are common legumes used as green manures. They will, if inoculated properly, add considerable nitrogen to the soil as well as organic matter. This nitrogen is clear gain to the farmer and will often save him from the necessity of applying a commercial nitrogen fertilizer.

From Davis's *Productive Farming*, J B Lippincott Co

COWPEAS FOR GREEN MANURE

The plowing under of a legume such as cowpeas not only increases the organic content of the soil but may add nitrogen besides due to the nodule bacteria that grow on the roots of such plants

Benefits of green manures

The effects of turning under green plants are both direct and indirect — direct as to the influence on the succeeding crop and indirect as to the effect on the physical, chemical and biological conditions of the soil.

Carbon, hydrogen and oxygen wrested from the air by the plant are added and, as organic matter constitute a clear addition If the plant is a legume and the nodule organisms are active, the nitrogen content of the soil is also increased The mineral portions of the plant have, of course, come from the soil, but they are returned in a form more readily utilized again by plants As time goes on and the store of organic matter increases, this quickly available mineral matter is an important factor It forms a circulating store of no mean dimensions.

Green manures cover the soil and catch soluble plant food that might otherwise be washed away In this capacity they act as "cover crops." The nitrates especially are conserved in this manner. Green manuring plants with long roots tend to carry up food from the lower depths, thus concentrating plant nutrients near the surface of the soil. Again, the added organic matter serves as food for bacteria and stimulates all of the transformations already described. The carbon dioxide liberated by these activities becomes a factor in the solubility of other nutrients. The organic materials that result from this decay increase the absorptive power of the soil, and promote aeration, drainage, and granulation — conditions extremely important in the successful production of crops.

In fact it has already been emphasized that a soil, from the plant standpoint, does not exist unless a certain amount of organic matter is present.

Farm manures

Farm manure is a by-product of the farm It contains what is left of the crop after it has been fed to the animal. It is important in several ways In the first place it is formed in large quantities, a horse or cow producing from ten to twelve tons a year. Moreover, there appears in it 88 per cent of the nitrogen of the crop, 98 per cent of the minerals and 50 per cent of the organic matter, in all about three-fourths of the valuable constituents that came from the fields Again it is in a form whereby it can easily be returned to the soil In general, we use our soil too much as a mine, and return too little of the food removed therefrom Such practices cannot go on forever Here is a chance to economize, a chance to prevent waste, a chance to encourage and strengthen the forces at work in the soil We are entering an era when all waste will receive the frown of disapproval. Let us place ourselves beyond criticism

From Fippin's *Nature, Effect and Maintenance of Humus in Soil*, Cornell Reading Course for the Farm, N Y State College of Agriculture

WASTE OF MANURE

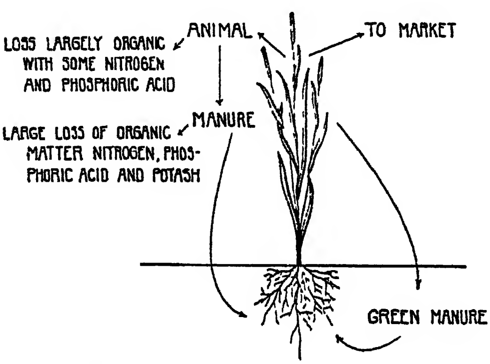
The careless handling of farm manure always results in the loss of valuable plant food that might be utilized with profit in the soil

In order to make the best use of farm manure we must know something of its general characteristics and how it affects the soil and the crop. In general, it may be said, it carries a large amount of moisture being about 73 per cent water and 27 per cent dry matter. Its percentage of plant food elements is very low, as it carries only five-tenths per cent of nitrogen, two-tenths per cent of phosphorus, and five-tenths per cent of potassium. This must not lead anyone to consider that it is not important as a fertilizer. Since it is applied in very large amounts per acre it carries to the soil in aggregate a large amount of food Ten tons of manure is equal to an application of five hundred pounds of a readily available commercial fertilizer It is no wonder that plants respond when manure is added to the soil Another characteristic of manure is that it has too much nitrogen in proportion to the phosphorus which it carries In other words, the phosphorus is a limiting factor and the manure is unbalanced. The "reinforcement" of farm manure with a phosphorous fertilizer, such as acid phosphate, is sometimes resorted to in order to increase the effectiveness of the other plant foods present.

About one-half of the plant food carried by manure is in an available condition for plant use. The other half must be simplified, and our friends, the bacteria, are called upon to do this work As the manure is voided by the animal it is found to be literally alive with germs We thought the soil contained a great many bacteria, but manure easily excels the soil in this regard. These bacteria begin immediately to tear down the complex compounds and as the manure stands in a sheltered pile the amount of available material continually increases. You have noticed how plants respond to well-rotted manure? The reason lies in its availability. Were it not for bacteria it would be hardly worth while to put our farm manures on the land. Thus the soil would soon be full of inert material of a very complex nature, containing plenty of plant food. This food would be, however, entirely beyond the reach of any higher plant that might be growing on the soil and would be worthless as a fertilizer.

Waste of manure

It is necessary to use some precautions in the rotting of manure due to two circumstances In the first place, if the manure is too loose and open, certain types of bacteria tend to reduce the nitrogen compounds to ammonia gas, and in this form it is readily lost. Such an unfortunate state of affairs may be partially prevented by keeping the manure moist and well compacted. In the second place, it is obvious that if the materials of the manure are becoming more and more soluble, undue amounts of water will wash away the valuable constituents. The placing of a manure pile under the eaves of the



From Lyon's *Soils and Fertilizers*, The Macmillan Co
Diagram showing the addition of crop materials to the soil either as green or farm manure Note the losses that of necessity occur in case the crop is fed to animals The fertility of the soil cannot be maintained by the use of farm manure alone

barn is almost a crime as far as this waste is concerned It is now clear why it is an advantage for manure to rot. If this rotting goes on in piles in the barnyard, the manure ought to be kept moist and compact and at the same time protected from excessive rainfall.

The first point where waste of manure may be reduced is in the stable. The use of plenty of litter to absorb the liquid and soluble portions of the manure is advisable. This litter or bedding also serves to keep the animals clean, a very important feature, especially with dairy cattle. Straw, shavings, and sawdust are used for this purpose. It is also necessary to have a tight floor if possible in order to prevent the liquid manure from running away before it can be absorbed by the litter.

Experiments have shown that very considerable savings may be made by carefully observing the points just mentioned

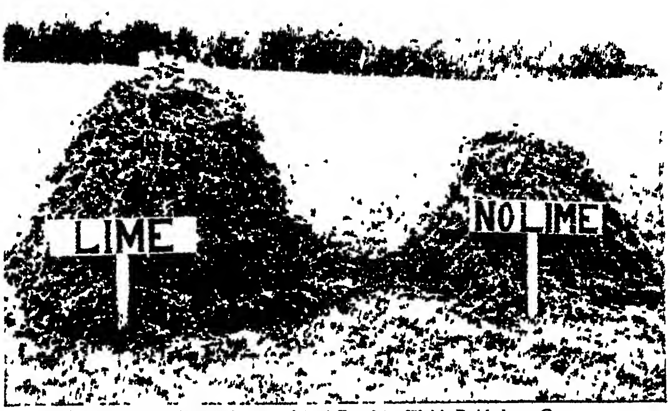
After the manure is produced the next point to decide is as to the best methods of handling it In general, it is most economical to haul the manure directly to the field Here it comes in contact with the soil and as the soil is such a good absorbing agent there is little chance for loss. It is not always possible, however, to place manure directly on the land. The soil may be too wet, it may be carrying a crop or it may be winter and the ground frozen or the snow too deep Under such conditions it is often necessary to store manure for short periods. This may be accomplished by piling it up under sheds or in pits, bearing in mind the necessity of keeping the pile moist and compact and sheltering it from excessive rain. The practice many farmers have of throwing the manure out under the eaves of the barn, where every condition for plant food loss is at its best, is wrong. One-half of the plant food value of the manure is thus very quickly lost. Not only this but only about twenty-five per cent of the organic matter of the manure gets into the soil due to the loss of gases produced by the action of bacteria.

To make the seriousness of the loss of plant food from manure more striking let us make a few calculations. The losses in the handling of farm manures amounts in general to about seventy-five per cent of its original value. This is a conservative estimate. The value of all the manure produced in stables, sheds, and barnyards in the United States amounts to about $700,000,000 in round numbers per year A seventy-five per cent money loss amounts to $525,000,000. Truly a tremendous waste. When we realize that only $100,000,000 worth of fertilizers are applied to our soils yearly and that this goes to only a few states, the true gravity of the situation is apparent. If fertilizers are unable to stem the waste, and if green manures do not replace this vanishing fertility, would it not be wise to be a little more careful with our farm manures?

Use of manure

Once a manure is in the soil what happens to it there and what functions does it perform? In the first place, it increases the organic matter of the soil thus tending to better granulation, drainage, and air movement. Chemical action is intensified in the soil by manure. It acts also as a food for bacteria as well as carrying many germs into the soil. With some soils such as muck, manure is added very largely as an inoculating material and not for its nutrients at all. Besides these effects, which are more or less indirect, manure adds large amounts of plant food. Even moderate applications of ten or twenty tons are equivalent oftentimes to from five hundred to a thousand pounds of a readily available fertilizer.

From the fact that only part of farm manure when added to the soil is immediately available, considerable residue must be left over for the use of the next crop. In fact, manure produces a marked effect for several years after its application. This residual influence has been noted in extreme cases to last for forty years. Ordinarily a paying effect persists only about four or five years, the length of a rotation or succession of crops. This residual influence of manure is a very fortunate thing as it allows us to store up in the soil considerable quantities of organic matter as well as plant food. Of all fertilizers, farm manure is the most lasting, lends the most stability to the soil, and is really one of the most important and economic factors in the maintenance of soil fertility.



From Whitson and Walster's *Soils and Soil Fertility*, Webb Publishing Co

LIMED AND UNLIMED ALFALFA

The use of lime with certain types of crops is necessary in order to obtain paying returns

A wise and careful farmer will try to utilize his farm manure in the most economical way. He will have tight floors in his barn and he will use plenty of litter behind his stock. Once the manure is produced he will draw as much directly to the field as possible. That which must be stored will be handled with such care as to cut down the losses due to leachings and fermentation to a low figure. Not only this, but the manure will be placed on the soils and with the crops, where the greatest good will result. While all of the losses from the soil cannot be controlled by the careful handling of farm manure, nevertheless, it is certainly worth the while of every farmer to be careful with this by-product. Even reasonable attention would save to the soils of this country millions of dollars of plant food which is now being lost in our streams and rivers, as well as thousands of tons of most valuable type of organic matter.

Lime

A number of substances are added to the soil with the idea of increasing productivity in an indirect way, through influences upon the physical, chemical, or biological conditions therein. Such materials are called "amendments," as they alter or change conditions within the soil. Some may carry plant food, but where they do, that influence is usually of minor importance.

Calcium is a plant food element, but it is practically always present in sufficient amounts to supply such needs. Its influence is greater in an indirect way, and salts of calcium have become our principal soil amendments.

The compounds of calcium which are mostly used are ground limestone (calcium carbonate), water-slaked lime (calcium hydroxide), and burned lime (calcium oxide). They are spoken of in general as "lime," a term when used in this loose way referring to all or any one of the three compounds. As calcium is the active constituent of these amendments, their relative effectiveness will vary to some degree upon their percentage of this element. On this basis 56 pounds of burned lime carries as much calcium as 75 pounds of hydroxide of lime and 100 pounds of limestone. Because of the caustic properties of the first two forms of lime and also because of their greater solubility, they are more active than the ground limestone and where quick results are desired, they are generally preferred. Over a long period, however, the results from limestone are about the same as from the other kinds.

Courtesy of Ohio Agricultural Experiment Station

SPREADING LIME

An even and uniform spreading greatly increases the efficiency of the lime application, providing it is later thoroughly worked into the surface soil

Benefits of lime

One of the greatest benefits of lime is the correction of what is called soil acidity. Acidity is a condition of the soil whereby such basis elements as calcium, magnesium, potassium, etc. become either lacking or unavailable. Such a state is bad for plant growth and many of the common crops do not do well under such a condition. Plant food does not go into solution, granulation is interfered with, and of greatest importance bacteria do not thrive. They are unable in an acid soil to work economically and some types cannot function at all. The nodule organism especially is detrimentally affected. Nitrification is also interfered with to a very marked degree. The seriousness of an acid condition is quickly reflected in the crop yield, and the farmer finds his harvests gradually dwindling.

The obvious way of correcting acidity is by the addition of some material carrying the necessary basic elements. Of all compounds lime seems to be the best, as it is plentiful, cheap, and effective. Applied in any of the three forms, the calcium seems to perform the necessary function of supplying active bases. The acidity is corrected, the sanitary condition of the soil is improved, and all the soil functions are placed on a normal plane. It is remarkable how nitrification is stimulated by lime. This has been shown by many investigators. The relation between lime and the formation of nodules on legumes is another vital factor in practical agriculture. Nitrogen fixation and transformation of all kinds seem to rely upon a plenti-

ful supply of lime Its presence in the soil is an essential to successful agriculture If it is lacking, it must be artificially supplied

Besides correcting acidity, lime tends to granulate a heavy soil The presence of the lime seems to draw together the small particles of the soil which are so prone to produce a puddled condition This action gradually causes the formation of crumbs and the soil becomes much more friable and mellow because of this action used but none of them have the lasting and favorable influence of lime None of them intensify and increase the effectiveness of other added materials as does the lime Farm manure, for instance, gives much better results if the soil is well limed Its decomposition is more thorough and its decay products of more value to crops Green manure is affected in the same way, while some commercial fertilizers give but little crop response unless the soil carries plenty of lime

From *Soil Sense*, The Dunham Co

GOOD SEED BED

A good seed bed increases the probability of paying results from the use of commercial fertilizers

Burned and water-slaked lime are particularly effective in this regard. Lime also seems to release plant food elements such as potassium, and force it into a condition whereby it may be useful to crops This is effected by the calcium exchanging places with the potassium in the complex and insoluble compounds of the soil. Lime then is one of the keys for unlocking some of the otherwise unavailable stores of plant food in the soil.

There are other compounds that may be added to the soil as an amendment. Gypsum, common salt, and sulphur have been

Lime is added to a soil in amounts proportional in general to the degree of acidity The quantity necessary to apply is called the lime requirement of the soil. The amounts are generally large, ranging from 500 to 2500 pounds per acre of the water-slaked lime and 2000 to 4000 pounds of the ground limestone. The fineness of the limestone is a factor in its effectiveness, a finely ground product being preferred to a coarse material. Due to cost of grinding, the ground or crushed limestone on the market is generally of only medium fineness.

Lime is best applied with a distributor, where definite amounts may be added uniformly over the surface of the soil This application is usually made on plowed land and then worked into the soil as the seed bed for the crop is being prepared In general the time and way of making an application of lime should be gauged by the labor and crop conditions on the farm

Commercial fertilizers

Soil additions of various kinds as they differ in their function may be roughly classified under four heads. green manures, farm manure, lime, and commercial fertilizers Green and farm manures exert not only a direct action upon plant growth but indirect actions as well Farm manure is especially effective in both of these ways, as has already been shown. Lime acts almost entirely as an amendment Commercial fertilizers on the other hand function entirely as a source of plant food or in a direct manner It is difficult to state the exact money value of such a material as farm manure, as its influence is felt in so many ways and over such a long period of time Its actions are also very complexly interwoven with many other soil factors Commercial fertilizers usually carry readily available plant food which can be utilized by the crop immediately. Very little residual action takes place Consequently the value of the fertilizer may be calculated in terms of crop yield Commercial fertilizers are bought and sold on a definite money basis expressed in dollars per ton. The value, of course, depends on the content of nitrogen, phosphorus, and potassium.

Fertilizer balance

The three primary elements of fertility exert certain influences upon plant growth. Nitrogen stimulates the growth of the tops, and imparts a deep green healthy color to plants. It makes the crop juicy and promotes rapid growth Because of its immediately visible effects the farmer is likely to overestimate its importance This is unfortunate as nitrogen is a high-priced constituent and may produce harmful results if present in too large amounts. Phosphorus is necessary for cell division, for the production of fats and for the changing of starches to sugar It improves the quality of the crop and has a great deal to do with the filling and ripening of cereals Potassium is essential for the formation and function of the chlorophyl or green coloring matter of the leaves It has to do with starch formation and the plumping of grains It controls the general vigor and health of the plant

Phosphorus and potassium may be added in large amounts to a soil and no harmful effects will result. Nitrogen, on the contrary, will bring about certain influences which are undesirable It will increase the above-ground parts of the plant at the expense of the roots, it will delay ripening, and it will weaken the straw in cereals Besides, it tends to lower quality and to encourage disease Fortunately, phosphorus and, to some extent, potassium, tend to counteract these bad tendencies, and when they are plentifully supplied in relation to the nitrogen all is well There seems to be a proportion or "balance" between the primary elements of fertility as added in commercial fertilizers at which the best results may be attained.

There is a "balance" in another way between the food elements If one is present in small amounts, it becomes a limiting factor in the growth of the crop. No matter how much of the other constituents are present, the crop cannot develop, due to a deficiency in this one element. The other elements are thus wasted and the full efficiency of the fertilizer cannot be realized. This is an "efficiency balance" as contrasted with the "health balance" already mentioned. When feeding animals we try to supply food with the right proportions of carbon and nitrogen. When this is attained the greatest return per pound of feed is realized. The analogy holds for the feeding of plants. We try to add a fertilizer carrying such proportions of nitrogen, phosphorus, and potassium that when added to the soil a balanced ration is supplied to the crop We may expect only under such conditions the maximum return for every dollar we expend in the purchase of commercial fertilizers.

A BIG CROP OF LETTUCE

Photos from American Agricultural Chemical Co.

A MAMMOTH CROP OF FINE CELERY

Fertilizer mixtures

The elements of plant food are of course applied to the soil in combination with other elements forming compounds Such compounds are called fertilizer "carriers" For instance, sodium nitrate contains sodium, oxygen, and nitrogen, the nitrogen making up about one-sixth of the compound We therefore say that sodium nitrate has 16 per cent of nitrogen or 16 pounds for every 100 pounds of the carrier Generally a number of the carriers are mixed together before applying to the soil Such a combination is called a mixed fertilizer Thus we might mix together dried blood which contains nitrogen, acid phosphate which carries phosphorus, and potassium chloride which contains potassium This would be a mixed fertilizer and a "complete" one as well, as it would contain all three of the primary elements. If it carried only two of the necessary elements it would be called an "incomplete" fertilizer Commercial fertilizers are generally complete.

The carriers commonly used by the fertilizer manufacturer in making up mixed goods may be listed under three heads according to the principal food element they supply Dried blood, sodium nitrate, tankage, and ammonium sulphate are nitrogen carriers Acid phosphate and basic slag are the principal phosphorus carriers, while potassium sulphate and chloride are used largely as a source of potassium. All of these are quickly available for the use of the plant

In preparing commercial fertilizers two things must be carefully looked to, first, the dryness and fineness of the mixture, and secondly, the percentage or "balance" of the food elements. In order to have a fertilizer which is fine, careful grinding is resorted to The dryness of the mixture is assured by adding some dry material, as sand or muck as a filler The farmer demands a fertilizer that will become neither moist nor lumpy as it will not under such conditions run through his fertilizer distributor readily The proportions of nitrogen, phosphorus, and potassium are carefully regulated by varying the amount of each carrier which goes into every ton of fertilizer. The two latter elements are usually present in a fertilizer mixture in about equal amounts, with the nitrogen from one-fourth to one-half as much The amounts of nitrogen must be kept down due to the ready availability of that element and to the quick and often undesirable response of the crop to its influence.

From Lyon's *Soils and Fertilizers*, The Macmillan Co

EXPERIMENTAL PLOTS

The effects of various fertilizers on crop yields are often determined on small plats accurately laid out and carefully controlled during the growing season

When fertilizers are placed on the market they are sold under brand names, or they may go by a letter or even a number The content of nitrogen, phosphorus and potassium is always on the bag or tag. This expresses the composition in various chemical ways too complicated for us at this point to inquire into. It is enough to say that the percentage of nitrogen is expressed first, the phosphorus (as phosphoric acid — two elements of phosphorus and five elements of oxygen) next, with the potassium (as potash — two elements of potassium and one of oxygen) last Thus a 2–8–10 fertilizer contains two per cent of nitrogen, eight per cent of phosphoric acid, and ten per cent of potash. Some common crop mixtures are given below:

Legumes	1–8–10
Grains	3–8–5
Garden	4–8–10
Grass	3–6–9
Orchards	2–5–10

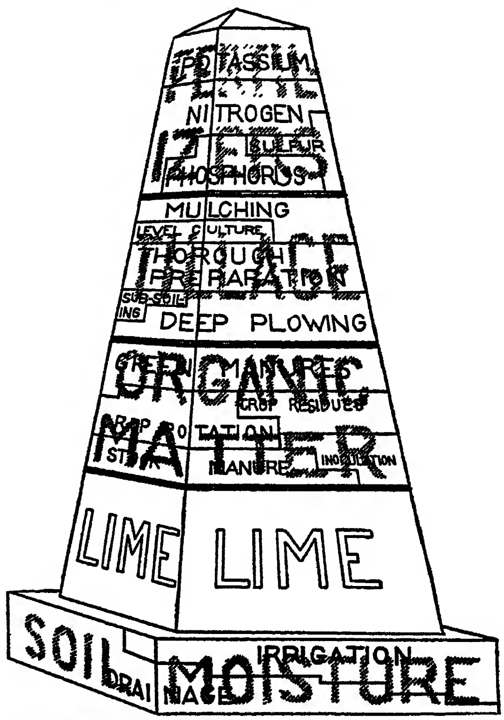
Use of fertilizers

In using fertilizers two points must be observed Buy a ready available mixture and a mixture that is suited to the soil and the crop to be grown A sandy soil will need a different mixture than will a clay soil with the same crop This is due to the fact that most of the food used comes from the soil The fertilizer is supplementary and should supply the deficiencies The adjustment between the fertilizer, the soil, and the crop makes a very intricate study. It cannot be solved by rules and is never fully determined for any soil To complicate the question still more the amount of fertilizer to apply per acre comes in If you add too much you will overfeed the crop and waste valuable plant food. The increased crop yield may not pay for the fertilizer On the other hand, if the application is too small you lose a chance for a profitable investment One-half of the fertilizers added in the United States today are wasted This is due partly to a poor adjustment between fertilizer, soil, and crop Most of it can be laid to a too lavish application per acre

A great many people have an idea that all that is necessary in order to secure good crop growth is to apply plenty of fertilizer. This is a mistake Food does not constitute all that is necessary for the development of the plant. The food in the soil, the organic matter, the physical and biological relations, lime content, drainage, and water relations all play a part. The seed, the climate, the season, and disease also must be reckoned with If this is the case, it is evident that in order to get the best results from fertilizers every other soil condition must be at its best. It is like feeding a beef animal The best gains are made when the animal is in the best health. A healthy soil is a factor in fertilizer practice It involves the practices already discussed With an active bacterial host working under the best of physical and chemical conditions fertilizers become a beneficial supplement to plant growth instead of a harmful drain upon the fertility of the land. Fertilizers will be used in larger amounts as the years pass by.

Maintenance of soil fertility

The maintenance of soil fertility involves all of the practices already set forth. Every one is important Not one can be neglected A farmer must drain, he must till, he must lime, and he must fertilize Moreover, each practice must be adjusted not only to the soil itself but to every other practice and this adjustment must be maintained from year to year. The rational



From Fippen's *Introduction to the Principles of Soil Fertility*, Cornell Reading Course for the Farm, N Y State College of Agriculture

Diagram representing the essentials of soil fertility Beginning at the base the order of adjustment is progressively shown moisture, lime, organic matter, tillage and fertilizers The primary practices by which these five essentials are controlled are also indicated

aim of all agricultural operations — the growth of paying crops and the maintenance of fertility — will then be realized. In improving the soil no rules can be given. Only general principles such as already discussed can be cited Success depends entirely upon knowledge, skill and judgment. As our understanding of the processes of production increases and our control over these processes is extended, the art and the science of Agriculture will become as one. We may then boast of an agriculture self-sufficient and inexhaustible.

A GROUP OF POLAR BEARS AT HOME IN THE HEART OF EUROPE

Polar bears, whose natural home is amid the ice of the North Polar regions, live for many years in a temperate climate, and here we see how Herr Hagenbeck solved the problem of furnishing them with a home in the heart of Europe, in Germany, at Stellingen Park, Hamburg. Polar bears rarely rear cubs in captivity.

THE BEAR AND HIS COUSINS

The Principal Species of Bears and Their Close Allies — the Pandas, Raccoons and Kinkajou

THE MONARCH OF THE FROZEN WORLD

NATURALISTS have no difficulty in agreeing that bears constitute a group by themselves, but there are no water-tight compartments into which we can rigidly divide animal life To attempt such a classification is to contradict nature

Nature is never brusque, she makes no abrupt boundaries She does not arbitrarily create a type without experimenting further with variants. She is adaptive rather than inventive. We often have to dig deep to fathom the secret of the means by which she has arrived at the results before us. If we could conceive of nature as a personal entity of human attributes, we should imagine her laughing at pitfalls into which her devices lure us.

We have a case in point in the bears, a family of carnivorous animals, widely distributed, but distinct and apart from all other animal creation. So we used to say. Some fifty years ago, an animal known as the great, or short-tailed, panda was discovered, and men added it to the ursine family, calling it the parti-colored bear, which is the name that any naturalist, ignorant of its anatomical structure, would apply on first seeing it today. But, bear-like though it be, it is no more a bear than a wolf-hound is a wolf. Related to the bears it is, but it belongs, not to the bear but to the raccoon family.

It is a link which had been missing from our living chain of animals, and it serves to connect the raccoon family with the bears. When the destinies of the dog family were being shaped, another line of carnivorous animals was at the same time being slowly evolved.

With the same ancestry as the dog, they became, on the one hand, bears, on the other, pandas and raccoons. And now that the mystery is solved, we divide all these animals into only two families, of which the bears form the first. The bears and raccoons preserve for us the method of locomotion common to the ancestors of themselves and of the dog family.

All the bears and raccoons are plantigrade — that is to say, they walk flat-footed. So did their remote mammalian ancestors. The dogs have greatly modified this method — they have specialized means of locomotion But the bears have, to an equal extent, advanced upon their primitive model in the matter of dentition. The teeth of the dog are fashioned for the eating of flesh, and though wolves and jackals, and some other members of the tribe, eke out with a vegetarian diet, it is from necessity rather than choice. The teeth of the bear, however, are adapted practically to every form of diet. In fact, vegetable feeders are the rule rather than the exception among bears. Even the polar eats weeds from the sea, and browses during the short arctic summer upon such vegetable growths as his habitat affords; while berries, grass, and the foliage of trees are as acceptable to the savage grizzly bear as honey, deer or horse meat.

In bulk and physical strength the gorilla has become the greatest of the Primates, and the bear occupies a corresponding position among the Carnivora. By making the best of the plantigrade action with which he began his career, the bear has become one of the most formidable and widely distributed of all our animals.

He shambles along in ungainly fashion, but has speed, and he can accommodate himself to practically every condition possible to animal life, excluding the realm of the birds and the haunts of the deep sea fishes. He can climb a mountain as easily as he can scramble up a tree; he develops a hairy growth upon the soles of his colossal paws to prevent his slipping on the ice, he can swim so well that one has been seen making its way at sea undistressed forty miles from land or ice, torrid climate or Arctic does not prove a barrier He can eat anything — fish, flesh or vegetable. He has nothing like so big a brain as the anthropoid ape, but such brain as he possesses has enabled him to adapt himself to circumstances better than any other animal, the dogs alone excepted. The gorilla has gone too far, yet not far enough, and needs millions of years to perfect himself, but the bear, with his primitive gait, has really done better, in all but mental potentialities, than even the lords of the Primates themselves.

Photo by W P Dando

A RISING HOPE OF THE ARCTIC

The polar bear cub is born naked and helpless, and is suckled by a dam which has spent the winter fasting in the snow

But there has been a fault somewhere in his career. The most promising of the bears emulated many other early animals; developed immense size and power, completely out-distancing all their dog-like relatives. Carnivorous mammals reached their maximum development in the colossal cave bear with which palæolithic man was brought in contact.

Why did the cave bears die while smaller bears of the same period survive? Probably strength and ferocity were its only assets Great bulk and mighty force are not always accompanied by the agility necessary for the maintenance of life in such a form, or the prehistoric monsters of the slime would not have vanished. This bear, which could kill nearly any other terrestrial animal, and drag its body to its cavern, there to gorge upon its remains, must have been almost the most dreaded of man's foes.

Yet man alone was hardly responsible for its extermination, though the brain that guided the hand in the shaping of a flint was a miracle of contriving mechanism in such an age. The paramount cause must have been the natural operation of the law which determines the issue of the struggle for existence; the smaller, more active, more adaptable bears probably starved out the more powerful but less agile and intelligent giants of the family.

Until the tale of the Alaskan bear was told, we of the present age had always considered the polar and the grizzly the heads of the family. The polar is big and formidable enough to satisfy the man who wanders northward, and with good reason, as we shall presently see. It is a wonderful testimony to the adaptability of the bear family that almost the finest members of the family should be found in the coldest, most inhospitable regions of the earth. The polar bear inhabits the whole of the Arctic Ocean, remaining near the edge of the ice cap, coming south in the winter, and retreating north in the summer, always keeping as near as possible to the sea margin. Here, amid the everlasting ice, it has attained magnificent proportions, a length of nearly nine feet and a weight of from 600 to 700 pounds being not uncommon in the adult. Its food consists of fish, the flesh of seals and the walrus, the carcasses of dead whales, and any animal or vegetable food — carrion or garbage — that it can secure. During the winter the female hibernates, snugly ensconced beneath the snow, while the males remain upon the prowl throughout the winter, having with them the cubs.

SIXTY POLAR BEARS THAT ENTERTAINED A CITY THEATER AUDIENCE

It was long supposed that the polar bear, ferocious and intractable, could not be tamed Here, however, are over sixty polar bears, not tamed, but trained to take part in an entertainment The bear in the foreground displays the hairy pads which enable him to run on ice and turn swiftly without slipping

Throughout the long winter, then, the female lies beneath the snow, and there brings forth her young. She must have within her system a sufficient reserve not only to support her own life during this long period, but to afford milk to her cubs as well.

These usually number two. They are born naked, blind, and helpless, unable even to wriggle a few inches to their dam's side should they be disturbed. Thus hidden in the close confinement of their snowy lair there is not much danger of their being lost in this way, of course.

Undoubtedly we should find there would be a serious thinning out of polar bears if the conditions of the nursing home were suddenly altered, for the polar bear is a stupid mother when removed from her natural surroundings. "Barbara," the splendid great she-bear at the London Zoölogical Gardens, several times presented her lord with cubs, but on each occasion she let them die — not through lack of affection, but from sheer stupidity, carrying them naked and blind and tender out into the freezing air of the open space beyond her den. Polar bear cubs flourish in a snowy crib in the coldest land in the world, but they die of pneumonia when their dams are at liberty to carry them with foolish pride out into the open in the winter of a temperate climate.

Polar bear dams are really as unwise, in conditions such as these, as some human mothers who have, in the twentieth century, to be compelled by law to clean and ventilate their rooms. In freedom the polar bear has not the temptation to expose her offspring until they are furred, active and strong.

Many travelers' tales attest to the strong maternal affection among polar bears

Nothing could exceed the pathos of an oft-quoted example of this fidelity cited by Captain Phipps. A dam and her two cubs approached an exploring frigate which was frozen in the ice, encouraged by lumps of flesh thrown to them by the sailors on board. These the old bear carried away singly, laying every lump before her cubs as she brought it; and, dividing it, gave each cub its share, reserving only a small portion for herself. The sailors shot the cubs and wounded their dam. "It would have drawn tears of pity from any but unfeeling minds to have marked the affectionate concern expressed by this poor beast in the last moments of her expiring young. Though she was herself dreadfully wounded, she carried the lump of flesh she had fetched away, as she had done others before, tore it in pieces, and laid it before them; and when she saw that they refused to eat, she laid her paws first upon one and then upon the other, and endeavored to raise them up. All this time it was pitiful to hear her moan When she found she could not stir them she went off, and, when she had got to some distance, looked back and moaned, and, that not availing her to entice them away, she returned and began to lick their wounds. She went off a second time as before, and, having crawled a few paces, looked again behind her, and for some time stood moaning, but the cubs still not rising to follow her, she returned to them again, and with signs of inexpressible fondness went round, pawing them and moaning. Finding at last that they were cold and lifeless, she raised her head towards the ship, and uttered a growl of despair, which the murderers returned with a volley of musket-balls. She fell between her cubs, and died licking their wounds."

The arctic bear one of the few animals not terrified by the scent of man

To restore the balance it is necessary to remember that the polar bear is not always the innocent victim, as in this case. A polar bear which, after a fair chase, will run down, kill, and eat a man, will creep noiselessly upon another as he sits on the ice, strike him down with its paws, then draw off to see if he is dead. This fearlessness of the bear in the presence of man is an interesting feature, for the same temerity does not mark the attitude of all the ursine family. Nor does the same attitude characterize all arctic and subarctic animals. There is something in the scent of a bear which is terrifying to nearly all other animals save man, and there is a terror for all other animals in the scent of man.

This has been very interestingly shown by a traveler who visited the Upper Yukon. On one occasion he killed a grizzly she-bear far up among the mountain peaks. The bear's cub, which was quite tiny, faced the hunter without the least sign of alarm, and he determined, if possible, to capture it alive. When he got to within six feet, the cub, for the first time, caught the scent of man; and, after sniffing several times in acute terror, it raced away at such speed as to render pursuit useless.

On another occasion a cow moose and her calf allowed the hunter to get within fifty feet of them, and to take a photograph without their moving Yet the moment he moved around so as to give them his "wind," they "jumped as if receiving an electric shock," and fled like the wind. But it is apparently not so with the polar bears.

The monarch of the frozen world displays a good deal of cunning in stalking its prey, and considerable intelligence in its choice of hunting grounds. And there is something to be said for the intelligence of a huge beast which has learned safely to cross rotten ice The polar bear, faced with such a problem, stretches himself flat at full length, with all four limbs widely outstretched, and, by thrusting with his hind feet or gripping with the hairy soles of his forepaws, can safely overpass a stretch of bad ice which would engulf him if he tried to walk across it And cannot something be said for the reasoning power of the brute which, seeing for the first time a trap set by man, avoids it? Nansen's men baited one near the *Fram*, and watched a bear approach. It badly wanted the lure of tempting blubber, but it went all round the trap, examined its framework, dubiously shook its head, walked a second time round it, followed the wire upon which the trap depended, made another general survey, gave its head another and final shake of suspicion and disapproval, then stalked determinedly away. It is in the highest degree unlikely that that bear had ever before seen a trap of any kind.

The brown bear was a very early inhabitant of ancient Britain

The brown bear was one of the owners of ancient Britain. The Romans found it there upon their coming, and exported the animal to Rome for sport in the circus. Down to the time of Edward the Confessor the town of Norwich had yearly to furnish one bear to the king, but bears seem to have disappeared from England about the beginning of the ninth century, having vanished from Ireland a century earlier.

However although he has been exterminated in the United Kingdom, the brown bear still maintains himself, except in populous areas, practically throughout Europe, and the whole of Asia northwards of the Himalayas, Siam and Japan, and throughout extensive portions of America.

It is perhaps natural that an animal having so extensive a range should show considerable local variations, both as regards size and coloration The Syrian bear, the snow or isabelline bear of the Himalayas, and various brown bears of America have, with others, all been con-

A BROWN BEAR AT LARGE
Here is a brown bear enjoying the freedom of Yellowstone Park

sidered from time to time as different species. The highest opinion, however, groups them all in one species. The brown bear is more often herbivorous than not, feeding upon bulbous plants, upon grasses, upon fruit, nuts, berries, and cultivated crops; but it will kill and eat animals, from mice to men. It should be added that, as a rule, the brown bear will, if possible, avoid an encounter with man. It suffices for the bear to get a man's scent; it will bolt. If pressed by hunger, however, or if cornered, then it will fight — and kill and eat a man as readily as will a man-eating lion or tiger.

During the winter the brown bear hibernates It seeks the shelter of tree or cave; it scrapes a hole beneath a fallen tree, it may even enlarge burrows begun by other animals When it goes to rest it is fat and sleek Instinct teaches the animal when its condition is such as to warrant its going to its winter bed After a bad season, in which food has been scarce, it will not retire at the normal time, but eagerly continue searching for food which shall enable it to lay up within its body the store of fat necessary for the maintenance of its life when all its functions, save respiration and circulation, are suspended.

When it emerges from its hiding-place in the spring, the female bear brings a couple of cubs in her train; she has supported herself and them, since their birth, upon the store accumulated within her own organism in the preceding autumn All the bears fresh from hibernating are lean and hungry They feed voraciously on a vegetarian diet, or they may raid herds of cattle or droves of horses, if these be handy and other forms of food scarce.

The great brown bears have the distinction of being the giants of the family

The brown bear of Kamchatka lives for a time entirely upon the salmon that crowd the river waters. Entering the water, it faces down the stream, and stands perfectly still The fish probably regard its massive limbs as the trunks of trees and fearlessly approach. Then like lightning the forepaw is raised, and a swift blow is delivered; the fish is transfixed by the terrible claws, and the bear leaves the river to eat as much of the fish as appeals to him. No matter what the size of his prey, he, like the otter, always quits the water to make his meal on land, and during the season the banks of the river are found strewn with the remains of fish which he has left.

The great brown bear of Alaska differs little in habits from its European and Asian relative, though it is larger. Specimens from Kadiak Island are said to reach a length of ten feet from the snout to the root of the tail.

The Sitka bear is a smaller, though still very large local race; and the Yakutat and Kidder's bear of the mainland are huge animals All these Alaskan bears are reported to be less fierce than the grizzly, though far exceeding the latter in size They will kill human beings, but they are really omnivorous, and eat fish, flesh, fruit, roots, grass, herbage, kelp, and berries They do not scorn the mice and ground squirrel or any other animal that they can catch.

The powerful grizzly bear whose savagery has become fabulous

The famous grizzly has enormously developed his claws, and this has caused him to sacrifice his tree-climbing powers. Whatever may have been its dimensions in the past, the grizzly does not, on the average, much exceed 6½ feet today. In view of this, it is interesting to remember that there are brown bears in Europe measuring 8 feet, and that the largest of the Himalayan bears run to from 7 feet to 7½ feet But, in truth, *Ursus horribilis*, as formerly known in the high ranges of the Sierra Nevada, was a terrible enough beast, said to have weighed as much as 1800 pounds, and certainly from 1200 to 1400 pounds In that region these bears were poisoned upon a large scale, for it was impossible to keep flocks on account of their ravages.

The grizzly, though mixing his diet with freedom, is probably the most carnivorous of the whole family, and has been known to kill a bull bison with a single blow upon the neck from one of his mighty paws, and to carry away a male wapiti estimated to have weighed nearly or quite one thousand pounds.

As to size and coloring there is a most confusing variety in all our American bears. Hence the wide diversity of view among naturalists as to distinction of species, which ranges from the view of some students that only three species may be counted, namely: (1) black bears, (2) grizzly bears and brown bears, (3) polar bears, to the view of others that North America has ten species besides several subspecies.

The various bears that are regarded as of the same kind vary excessively in color from a very dark brown to white "It is not uncommon," says Wright, speaking of the grizzly of the Northern Rockies, "to see an old she-bear with three cubs, each of a different color, one, for instance, of a dark brown, verging almost upon black, a second of a light buff, and the third nearly white, or white as far back as the shoulders . . A great variety of color is also shown by the black bears throughout the Rocky Mountains, where these animals are to be found of various shades from dark brown to buff, and even, occasionally, of a uniform cream-color"

Possessed of immense power, it kills with tremendous blows from its forepaws, while its teeth can crush the bones of an ox.

That it is a courageous fighter is well known, but a specific example of its courage is afforded by a scene which Ernest Thompson Seton witnessed in the Yellowstone Park, where wild animals roam at will in a state of semi-freedom. A black she-bear and her cub were feeding upon a garbage heap in the park, whence she had driven a number of other bears. Towards evening a large grizzly approached to the manifest alarm and discontent of the cub She turned to her little one and gave a gruff signal, whereat

THE GREAT BROWN BEARS OF ALASKA, THE BIGGEST BEARS NOW IN EXISTENCE

The brown bears of Alaska have deposed the polar bears, which were long regarded as the giants of the family Polar bears have been known to measure nine feet long, but their Alaskan cousins occasionally reach ten feet, not counting the tail.

Formerly enjoying an immensely wide range all over the northern half of the American continent, the black bear is now necessarily finding its territory more and more restricted; but it still remains fairly numerous in the mountainous parts of the East and in the more thinly settled parts of the South, especially along the lower Mississippi River. The natural range of the species extends over the whole breadth of the continent from Central Mexico as far toward the north as the limit of forest growth. But as land becomes settled, the bear must go; no farm stock is safe from its ravages, even quite large animals being killed and eaten by it.

the cub scuttled up a tree, while she went towards the grizzly. She stood as high as she could, and set all her bristles on end, then, growling and chopping her teeth, she faced him. As he drew near she gave him a terrific blow on the ear. The larger bear, taken by surprise, recovered himself, then gave her a cuff which knocked her over. Nothing daunted, she jumped up and closed with him. They clung together, rolling over and over, biting and pounding, then separated and drew apart. The grizzly did not wish to continue the fight, and moved in the direction of the heap, but as he did so the black bear, though wounded, attacked him again.

THE GRIZZLY BEAR THAT CAN CARRY OFF A VICTIM WEIGHING 500 POUNDS

Courtesy N. Y Zoological Society

The grizzly bear has enormously developed its claws, and however exaggerated have been the tales of its savagery and size, it has veritably proved a terrible devastator of the flocks and herds in the neighborhood of the Sierra Nevada, until exterminated there.

This time the grizzly was on his guard, and he dealt her one blow which knocked her backwards, crash on an upturned pine-root. He followed her up, but she, desiring no more fighting, dodged him round and round the root, until he tired and sat up, enabling her to bolt to the tree in which her cub was secure, and to scramble rapidly up into the branches to safety.

The Himalayas have their black bear, readily identified by the inverted crescent of white on its chest. It is, for the most part, a forest-haunting animal, ranging from about the eastern portion of Persia, through Baluchistan into Afghanistan and Sind, thence through the forest-clad portions of the Himalayas to Assam, and so on to Burma. The species is found also in the islands of Hainan and Formosa, and in Tibet. The spectacled bear, so called from the presence of tawny rings round the eyes, is a small black species inhabiting the slopes of the Andes, and appearing in Chile, Bolivia and Peru. The bruang, the bear of Malay, is believed to be a near ally of the spectacled species. It is smaller and more agile than the other members of the family, and possesses an extraordinarily mobile tongue, the result, no doubt, of long ages of partly insectivorous diet.

The sloth bear which ravages the ant-hills of India

Our survey of the bears closes with the curious cumbrous Indian sloth bear. Measuring from 4 to 5½ feet, this bear differs from all the rest of the family in possessing two less teeth than the normal number, in the long snout, and the baggy, pendulous lower lip, and in its exceptionally long, shaggy and coarse hair.

It is a slow, ungainly beast, sustaining itself mainly on fruits, flowers, honey and insects, though not disdaining at times a meal of carrion, or a delicacy in the form of a dead beast's bones, which should have been the perquisite of the hyena. It has a great fondness for white ants, or termites, and has obviously specialized in their capture. Its immensely powerful claws enable it to tear open the hills of these insects, when it reveals an extraordinary power of suction and of propelling air from its mouth.

Then, after having gained access to the lower galleries of an ant-hill, it blows with great violence, scattering the dust and crumbled particles of the nest; then, with equal vigor, sucks out the inhabitants of the comb with such forcible inhalations that the larvæ from great depths under the soil are drawn forth.

The pandas, the connecting link between the raccoon and bear families

Passing now to the pandas, we have first the great, or short-tailed, panda, which, as already noted, is superficially so bear-like a beast as to have been long classed with the ursine family. Resembling the sloth bear, it has only forty, instead of forty-two teeth like the rest of the bears. Structurally it closely approximates to the true pandas, and the balance of evidence goes to class it with the raccoon family. Its fur, which is long and close, is for the most part white, but the eyes are surrounded by black rings, the limbs are black furred, while the shoulders are marked by a transverse bar of the same hue. In general outline, the short-tailed panda would pass as a very small brown bear of aberrant coloration. Its home is in Tibet and northwest China, and its diet, so far as is known, consists solely of roots and of the tender young shoots of bamboos.

No bear can retract its claws, but the true panda, which is popularly known as the "cat-bear," has the power of half withdrawing them. The panda has the true plantigrade walk of the bear, and the soles of its feet are covered with hair. In size that of a big, bushy-tailed cat, the panda is a superb tree-climber, but closely resembling the great panda in certain anatomical features, it is, like that animal, mainly herbivorous, but in captivity eats bread-and-milk and eggs and small birds. It hisses like a cat, growls like a bear, laps, at times, like a dog, but commonly immerses its muzzle and drinks by suction, after the manner of a bear. The panda is a native of Asia, but formerly ranged over Europe to the British Isles, in days when they had a subtropical climate and were abundantly forested.

The raccoon that frequently washes its food before eating

The raccoons themselves are mainly carnivorous, living upon mice, young birds, fresh-water tortoises, fresh-water mussels and insects, with an addition of nuts, fruit and corn Occasionally, however, a raid upon a poultry-run shows in which direction the animals' preference lies. There is one species, the crab-eating raccoon, whose diet is sufficiently indicated by its name. This is a semi-aquatic mammal, but, like the other raccoons, makes its home in the trees The raccoons are tree-climbers because they find no other place secure. Their food is sought chiefly upon the ground but they make their homes in hollow trees; they hibernate there in the colder part of their range, and there their young are born

They have the bear-like gait, and possess the same number of teeth as the sloth bear. The size of the common raccoon of the United States and Canada is in body about that of the house-cat, but the length of the legs and the bushiness of the coat make it appear larger. The back is highest over the hindquarters. The head is triangular, and the face foxy in form, which, with the patches of black about the bright eyes, and the sharp, erect ears, give it a very knowing look. This does not belie their disposition for they are extremely inquisitive and alert, and are eager to explore every nook and cranny where anything eatable may be hidden, thus finding many insects and their larvæ, worms, etc , that a less lively intelligence would overlook.

The favorite resorts of the raccoon are retired, swampy lands covered with tall trees among which run small watercourses. The animal never seems quite comfortable without frequent access to water. Moreover it is fond of frogs, crayfish, and mussels, which it opens dextrously; and along the seashore it feeds largely on the oysters and other shellfish exposed at low tide. It watches, too, says Audubon, the soft-shelled turtle when she is about to deposit her eggs in a hole in the sand, and quickly digs them up for its own use as soon as opportunity offers.

It enjoys birds' eggs, robs many a nest of its eggs or fledglings, and, if able, catches the bird itself. This makes the raccoon a pest to the poultry-keeper, and the thief is not only extremely cunning at this work, but bloodthirsty, for he is likely to kill far more of the flock than he can eat.

Being particularly fond of sweet substances, the raccoon is occasionally very destructive to sugar-cane and Indian corn, where fields of these plants grow near the woods. While the ear of the corn is still young, soft and tender, "in the milk," as they say, troops of raccoons will sometimes invade a field at night (when the animal does most of his foraging), and do extensive damage, not only by eating the ears, but by breaking down great numbers of stalks In short, the raccoon is omnivorous and voracious, and in its feeding it shows one very peculiar habit, that of washing its food whenever it has a chance It will carry its food to the nearest water, and holding it squirrel-fashion in its front paws, will dabble it again and again in the water before putting it in its mouth.

When taken into captivity young, raccoons make interesting, although somewhat troublesome pets, because of their restless curiosity. "Nothing," writes Dr. Godman, "can possibly exceed the domesticated raccoon in restless and mischievous curiosity if suffered to go about the house. Every chink is ransacked, every article of furniture explored, and the neglect of servants to close closet doors is sure to be followed by extensive mischief." They are exceedingly fond of dabbling in water, a tub of which ought always to be provided for them. No animal is more fond of play. "They are frequently seen," to quote Godman again, in reference to his pets, "sitting on the edge of this tub, very busily engaged in playing with a piece of broken china, glass or a small cake of ice. When they have any substance which sinks, they both paddle with their forefeet, with great eagerness until it is caught, and then it is held by one, with both paws, and rubbed between them; or a struggle ensues for possession of it, and when it is dropped the same sport is renewed."

Raccoons choose as a home a hollow in a tree, which is made smooth within, but not furnished with straw or any sort of bedding. Only in the colder parts of the country are they confined to their dens in winter, for moderate cold does not trouble them nor interfere greatly with their hunting, which in winter, in the northern States, is chiefly for mice. Three or four cubs are born in May, and by late autumn they are large enough to set up for themselves

The cooperative hunters in the forest of Central America

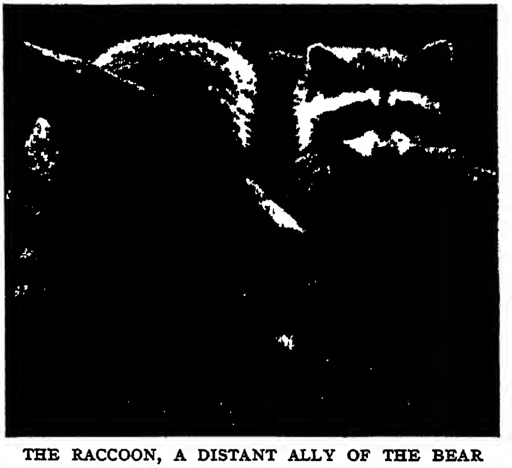
Several other animals come into the raccoon family — the cacomistle, a dweller in well-watered woods, and an enemy to poultry, the bassaricyon, an allied genus peculiar to Costa Rica, Panama and Ecuador, the kinkajou, with monkey-like appearance, and the coati, common to Central and South America.

The kinkajou, as the only member of the family which has developed a prehensile tail, is perhaps more completely at home in the trees than any of the others. The natives regard it as a type of monkey, and it has a lemur-like appearance But the paws are paws, not hands, armed with powerful curved claws, not nails, and the dentition is unmistakably that of the raccoon family. Equaling a full-grown cat in size, the kinkajou eats small mammals and birds, fruit, and honey. In moving through the trees kinkajous, which collect in troops, take considerable leaps from bough to bough. A strange development for a distant relative of the polar bear!

The cacomistle belongs to Mexico, but is also found in Arizona and southern California. It resembles the raccoon, but is more elongated and slender, and has a long, bushy tail elegantly ringed in black and white. Hence a common name is ring-tailed cat, or American civet-cat. It is a dweller in the woods, making a moss-lined nest in a hollow tree. It often grows bold and enters the miner's tent, and plunders his provision-bag, thus sometimes getting caught. It is easily tamed and repays all kindness by keeping the house clear of mice.

Two species of coatis are known, one common to Mexico and Central America, the other inhabiting South America, from Surinam to Paraguay. With its short and sturdy limbs, its plantigrade gait, and its excessively long snout, the coati has for its German name a description signifying "the proboscis bear"

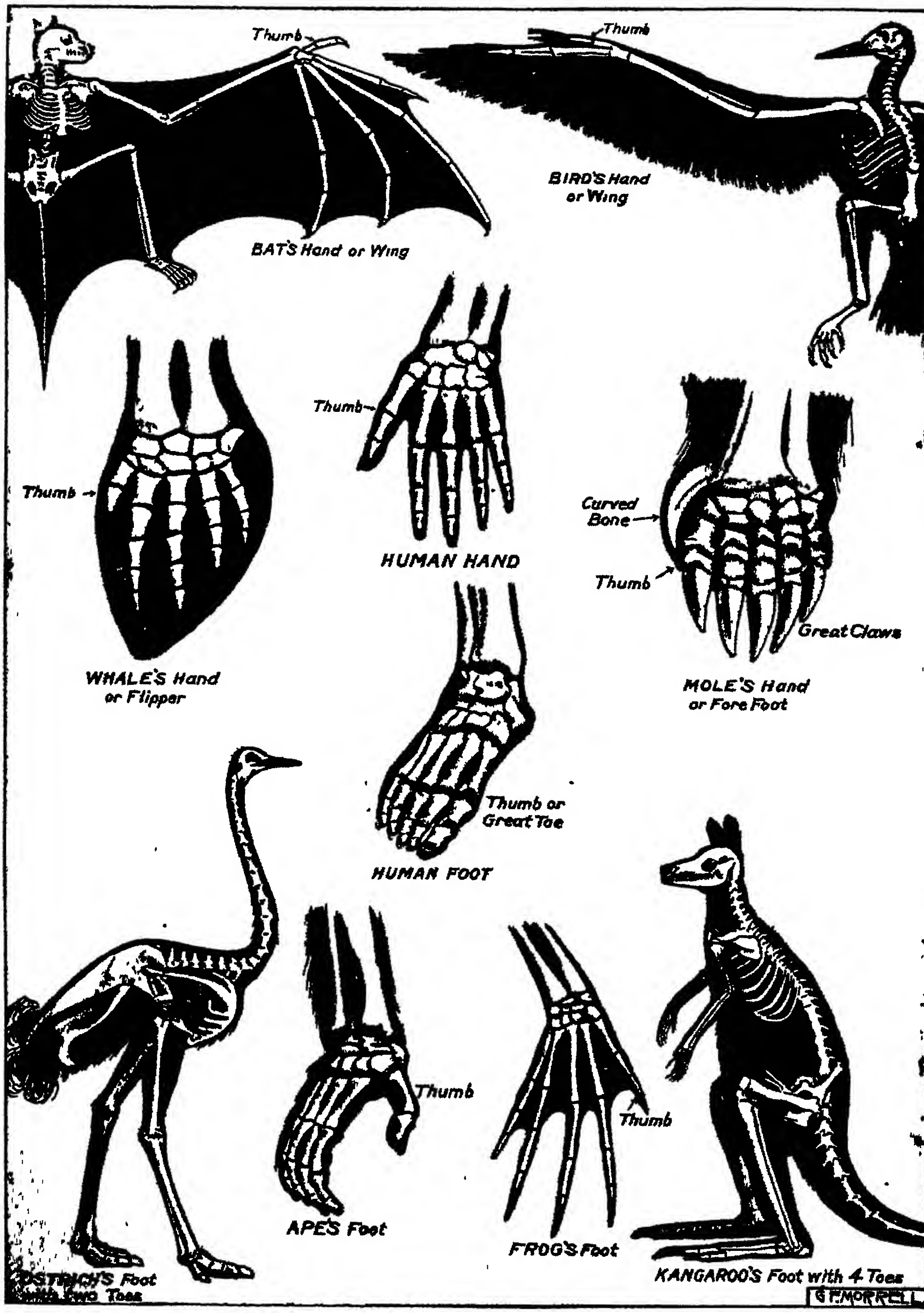
These animals are good climbers, and chase lizards among the trees The reptiles thus pursued drop to the ground, only to find a second detachment of the animals hunting below in obvious agreement with those in the branches overhead. The coati can be easily tamed, and makes a docile and interesting pet. All the members of the raccoon family, except the aberrant pandas, are natives of the American continent, the home of the majority of the bears.



THE RACCOON, A DISTANT ALLY OF THE BEAR
Although so unlike a bear, the raccoon is connected with the bears through the great panda

The contrast between these distant allies, the Alaskan giant and the pigmy coati, is a startling one, but not more so than the difference between a typical elephant and the degenerate elephants no bigger than Shetland ponies which once had their home in Europe; and not more startling than the contrast between a polar bear and a hairless Mexican dog of today. Bears and dogs are kin, bears and the prehensile-tailed kinkajou are kin, more distantly, but clearly connected through the pandas. We place them in different families today, of course, but there is no doubt as to their common origin.

THE MECHANISM OF MAN AND HIS NEIGHBORS



On this page are a few examples showing how man is ill adapted for flying, burrowing, climbing, swimming, running and leaping, in which things the bat, bird, mole, whale, frog, ape, ostrich and kangaroo outclass him. Yet man, with his mind, has become a creator, and has made his body the simple, all-capable, adaptable, supple, obedient and limitless instrument of his creative mind.

MAN MADE FOR THE UNIVERSE

The Human Instrument by which the Mind of Man Works out its Creative Purpose in the World

THE AMAZING MECHANISM OF A HUMAN BEING

WE repeat that man is body and mind, or body and *psyche* — for "mind" is really an inadequate word — or "body, soul and spirit," in the language of the past We must remind ourselves of this, because when we consider the body in detail, as is done by the sciences of anatomy and physiology, we are constantly tempted to suppose this is all

Only when our survey is finished, and we realize that it has scarcely been begun, and that all the ultimate questions have been left unanswered, do we realize that, however deeply we have probed with the knife and peered with the microscope, we have only seen one aspect of man, and there remains the psychical side, which escapes our grasp. It is probably true to say that some cannot study anatomy and physiology without passing into a stage of materialism, in consequence of the compelling and absorbing nature of these studies and their convincing character, as far as they go.

Some never pass further, but those who turn from the dissecting-room and the laboratory to living men and women, doing, daring, fearing, thinking, creating, inevitably pass through materialism as a child passes through chicken-pox, and they are forever immune thereafter. Here we are to study the whole man, and must devote a just share of our time to what is beyond touch or vision, but is much more obviously real than anything that can be touched or seen. As we study, we shall find ourselves constantly asking a question which men have asked from the beginning of time. What is the relation between mind and body?

The answer may never be forthcoming, but it is immeasurably better to have asked it than never to have faced it at all

Here, then, we deal with man's body, and at the first moment we see that our subject may be divided into two parts. On the one hand, we may study the form, structure and construction of the body, in general and in detail; and, on the other, we may study its working Anatomy — literally cutting-up — is the study of structure, and physiology is the study of function. These go hand in hand, and can only be studied intelligently together.

We cannot study the function of the heart without first identifying the heart; and our anatomical description of the heart, its walls and the flaps inside them, cannot even be intelligible unless we know its function, and understand that the walls squeeze a fluid within them, and the flaps are valves to secure the right working of this living pump. Always, therefore, anatomy and physiology are studied together; and in most parts of the world the professional teachers of physiology take over and deal with the whole of what is called "minute anatomy," that is, the anatomy of the tissues, which is conducted with the microscope, but is just as much — or more — anatomy as is the jointing of the skeleton. This minute anatomy is one of the great sciences of the future, for it carries us much nearer the very home and temple of life than any naked-eye anatomy can do, though evidently we require first to learn what the unaided eye can see, and then go in detail, with every possible aid to vision, over each organ and tissue of the body.

The first requirement is to consider the body of man as a whole, taking a view of him as he really is under his clothes

Even at a glance much is to be learned Clearly *the body of man is an animal* To say, as we often do in cynical or would-be scientific vein, that man is an animal is simply to confound things that are obviously different — which is exactly the opposite of any scientific procedure. But to say that the body of man is an animal is strictly accurate, and neither more nor less than the truth. It is to be hoped that this simple phrase may be accepted some day. If we are not offended at realizing that our bodies are made of matter, as chairs and rocks are, we need not be offended at realizing that this matter is put together and built up on a particular plan which is so definite and peculiar, and yet so familiar, that we cannot think of dog or cat, or horse or mouse, elephant or monkey — nay, even of bird or fish or frog — without seeing that, whether we like it or not, the body of man is an animal, and an animal of a definite type, belonging to a definite class, together with certain other animals, and to the exclusion of the rest

A word as to this. Animals either have backbones or have none. Man has a backbone, and his body is therefore a vertebrate, or back-boned animal, and is almost immeasurably nearer the fish than, say, the bee All vertebrates, including man, classify themselves readily into fishes, amphibians, reptiles, birds and mammals.

The great difficulty of fitting man into his proper place

It is as clear that man's body is a mammal as that it is a vertebrate. He is a member of the mammalian class, agreeing with the essential characteristics of that class. All of its members, excepting the Ornithorhynchus, or Australian duckbill, bring forth their young alive — and the mothers suckle their young by means of special organs which are known as "mammæ," and from which the name of the order is derived Also, mammals are provided with hair, however scant it may be, as distinguished from the scales of the fish or the feathers of the bird.

But though the mammalian character of man's body is clear, and though its vertebrate character is not less so, we do find some difficulty when we compare him with his asserted allies. Some vertebrates have no limbs, as fishes and snakes But most have limbs, and the number is customarily four Never is it more — the sea-serpent, a vertebrate with more than two pairs of limbs, is unthinkable to the student of animal anatomy It is true that in birds the number may momentarily puzzle us, but we agree that it is still four, though as the bird hops or walks we only notice two We may call the bird a "biped," as the other two limbs (wings in this case) are not used in walking Then we see that man too is a biped, and thus, on this reckoning, seems to be nearer a bird than a mammal, though we have positively asserted that anatomically he is far nearer to the mouse or the elephant than to any bird. The evident answer, as we know, is that man has the typical four limbs of the vertebrate, and that these four limbs are mammalian, endowed with hair, not feathers, and that it is only the peculiarity of man's upright posture which appears to ally him more nearly with the bird than with the "four-footed" animals.

The vertebrate with skeleton inside and the invertebrate with it outside

We may note, also, that other mammals have gone their own peculiar way, as man has, and that the whale appears to answer very imperfectly to the idea of a mammal, but contrary to the general opinion of the laity, the whale is a mammal and not a fish. And man and the whale are far more closely related than man and bird, or man and fish

If we look at the body of almost any animal, we find that it evidently has hard parts and soft parts. Such a simple animal as an amœba has no hard parts, but it is so small that it needs no supporting framework or skeleton. But a lobster or an oyster, or a fish or a man — these have hard parts as well as soft; and at once we see an enormous difference between man and all other vertebrates on the one hand, and all invertebrates on the other.

The invertebrate always wears its skeleton outside, and the vertebrate its skeleton inside its body. Hard inside, soft outside, is the vertebrate rule, and to this rule man conforms It contrasts him, say, with the lobster, no less than the possession of a backbone, and it allies him, obviously, with the whale and the fish, against the "shellfish," which are not fishes at all

Thus we see the body of man, a four-limbed mammalian vertebrate, having an internal skeleton, supporting soft tissues, and covered with skin which bears not scales or feathers, but hairs which are almost unnoticeable in some parts but highly developed in other areas.

The vertebrate that has developed the most highly specialized skull

Like other vertebrate bodies, his has a long diameter or axis, coinciding with the backbone, and at one extremity of this long axis we find a typical head, while at the other we note that a visible tail is conspicuous by its absence The trunk is the central and axial part of the body and the head is a special development from its end of the trunk, even though we may no longer agree with Goethe and other precursors of evolution, who thought that the skull was modified from the vertebræ at that end of the backbone. This backbone is situated, of course, near the back of the body, though not outside it, like the back-armor of an invertebrate. On the opposite aspect of the body we notice evidence, in both sexes, of the presence of the typical glands which give their name to the mammalian order.

From near the head end of the trunk there springs one pair of limbs, and from near the tail end there springs the second pair. These, with their attachments to the trunk, constitute a series of appendages to the axial part of the body, so that anatomists are in the habit of speaking of the "axial" and "appendicular parts" of the skeleton parts. If, now, we compare these parts of man's body with the features of the bodies of the lower animals, we find an extraordinary measure of correspondence, going far deeper than the surface.

Man's perfection really the result of his extraordinary imperfections

Thinking of ourselves, in our typical erect attitude, we speak of *front* and *back*. The anatomist, however, who is bound to be a comparative anatomist, studying the different types of animal body simultaneously, is often compelled, of necessity, to think of man in the posture of the lower animals, and thus he uses the word "ventral," from the Latin for "stomach," and the word "dorsal" from the Latin for "back," to indicate the two aspects of the body, so that the same words can be used to compare upright man and horizontal mouse, when the details of anatomy are under consideration.

But at this point we begin to find that the body of man is strange and unprecedented when compared with its nearest allies Each of these allies, no doubt, differs from the others; the elephant and the bat and the whale are each strange and unprecedented enough. Man is so in a totally different way Each of them is made for a particular environment and kind of life; man appears to be made *for none in particular, and therefore for all.*

Consider, for instance, locomotion. This is a cardinal matter, for the body of man, like all other animals, requires to move in search of its food, whereas plants, whose food is almost everywhere, do not require to move. It follows that, whatever animal we study, we find it prepared for locomotion, *of one kind or another.* What kind, will depend not on chance or caprice, but on the inner nature of the creature, and its needs of diet, offense and defense and shelter.

The adaptation of an animal's limbs to its special functions

Thus, every sort of animal tends to become a specialist in one kind of locomotion or other. The bird takes to the air, and finds itself soon compelled to make all manner of sacrifices so as to be as good a flier as possible. The sloth takes to trees, and soon obeys the same necessity, like the fish or whale in the sea, the horse on land, or the hippopotamus in the river.

Now, every specialization necessarily involves sacrifice. Every animal that adapts itself to one environment, by so much unadapts itself to others Birds may swim and dive. and fish may fly, but these are special feats, and the bird must return to the surface or die, and the fish must return to the depths or die You cannot sacrifice fingers to make wings and fly, and then expect to play the piano, or even grub for worms, with your wings. The key that exactly fits one lock fails to fit another; and species and environment are just like key and lock. It must be a skeleton key, or a master-key, that can contrive to fit all, or almost all, locks

Now, if we look at the body of man from the point of view of locomotion, we are puzzled Seriously, if knowing nothing of him, we were suddenly faced with man, though we did know all other species, we should not know where to place him.

The physical powers of many animals that are superior to those of man

We should place him, indeed, among the mammalia, and so forth, but where to place him, literally, we should not know. Is his body meant to walk or run, climb, swim, fly or burrow? We have only to glance at bird, fish, mole, monkey, antelope, to answer such a question, but man's case is not so easy. Certainly, he was not made to fly, and never did Nor for burrowing, for instead of claws he has the most inadequate nails, which are useless for this purpose Certainly he can swim, and for some miles. But this is a rare feat, because his body was certainly not made nor are his limbs suited for the purpose.

Then perhaps man was meant to climb. His heavy, all-important head, which is such a problem for the swimmer, does not matter in the mechanics of climbing But again he disappoints us His body is far heavier, in proportion to his limb-strength, and especially his arm-strength, than a monkey's. His hands can grasp exceedingly well, but his feet are little help. The great toe cannot be opposed to the other toes, as the thumb can be opposed to the fingers; without the opposable great toe man can never develop tree-climbing powers.

The value of the tail as a fifth hand for a climbing animal

Every boy who has been taught to climb a rope, and grasp it with his knees and feet, knows by personal experience how wide is the contrast of climbing utility between feet and hands, but the ape and the monkey know no such difference

Man's climbing is thus what his swimming is — a feat, and has to be learned by the nervous system and has to be always carefully directed against serious difficulties If we have any doubt of the strange falling off of man's body in this matter of climbing, we may remember the expert use by the monkey of his tail. Not only do many monkeys use their tails as a fifth hand — and one cannot have too many hands for climbing — but even those which do not actually grasp with their tails use them for purposes of balancing, when they walk along a branch The tail touches the branch behind, sometimes on one side and sometimes on the other, partly helping the balance mechanically, and partly doing so by sending hints of the body's position up to the balancing center in the nervous system

Man's great inferiority in two important factors of life

There remains nothing but walking and running Doubtless man walks and runs very well — for him. But in point of fact man's ordinary mode of locomotion, though his best, is by no means perfect. In any kind of locomotion, we chiefly consider two things — speed and endurance

These are the two factors that matter for life; and we find animals that live by the one, and those that live by the other, some having much of both. We recognize these two points in our sports, with their sprints and their long-distance events Man is instantly outclassed by scores and hundreds of animal competitors in either kind of trial. His sprinter cannot catch a dog or a cat or a rat, because these animals have four legs to his two. With man's fore-limbs withdrawn from locomotion he has lost any chance of competition as walker or runner at any distance.

But his plight in the only form of locomotion of which he can at all boast is much worse than any racing can show His feet, pitiably inadequate for climbing, are but little better for walking Their nakedness is deplorable No claws, retractile or fixed, no velvet pads, no hoof, no thick, dense, resistant development of skin, such as the elephant has, nothing but a naked, soft-skinned sole, which any little thorn or jagged stone may disable We wear boots and shoes, our primitive brothers wear what they can make, bind something round their feet But with nothing—what a quandary! Do we not see what a remarkable fact it is — that practically nowhere can man walk barefoot, and yet his body is adapted for nothing else?

The veins of man that are unsuited to his erect attitude

With feet which cannot climb, or walk unprotected, man need not be surprised to find that the erect attitude, which leaves his inadequate feet unaided by his hands, is by no means suited to the rest of his body. The walls of veins are thin, and apt to stretch Therefore veins have valves in them, to prevent the blood from surging backwards and to limit the weight of blood that must be supported inside any length of vein. These valves are found exquisitely placed, say, in cat or dog, so that the risk of injury to the vein shall be as small, and the advantage to the onward circulation of the blood shall be as great, as possible. Man also has valves in his veins, and could not do without them.

But, behold, they are not where they would be most useful. They are distributed throughout the veins and limbs in just such fashion as would be most useful for a four-footed creature, walking on ground or bough, with its backbone horizontal. But man walks erect, with a long, straight line up and down from hip to ankle, and he pays the price. He cannot walk or run or stand for long without his feet swelling, because the circulation of the fluids upwards from the feet, against the pull of the earth, and with the valves of the veins misplaced, is arduous, and soon becomes imperfect.

Man the paragon and man the paradox of animals

Such being the anatomical facts, man is found everywhere, as no other creature is, and wherever man is found he is lord of the earth The condition of this preeminence is in his mind, and his body serves it by being "jack of all trades, and master of none" He has not specialized his body to fly, walk, swim, burrow climb, but it is sufficient instrument for making flying-machines and railroads, and boats for the surface and the depths, for digging mines and building lofty skyscrapers No other creature has gone along this road — the one open road of life — and thus man's body, compared with that of any other creature, is a sort of nondescript, the least specialized, because most adaptable.

This, that, or the other animal has been made a key to fit and turn the lock of a particular environment Man the creator has a mind which makes him, at will, a key to fit and turn almost any environment, even to make new environments such as nature knew nothing of before his day.

The marvelous instrument by which we see the world

This principle — that he is to be capable of anything, and that therefore his body must not be mechanically specialized for any one thing — applies to the whole of his life. We have here illustrated it from the case of locomotion, because that is fundamental for any animal, and because the illustration is so clear. But it applies everywhere.

For instance, if we turn from locomotion to sensation, no less important, we may well begin by looking at the eye. When we do so, we find that this organ, marvelous though it be, is imperfect in many ways. Forty years or so ago, the great Helmholtz said that if the eye were sent him by an optical instrument maker, he would return it as most unsatisfactory in structure and design Huxley saw more deeply when he pointed out that the eye is imperfect as a telescope, imperfect as a microscope, imperfect as a camera obscura — but it is something of all these.

Admirable is the highly specialized eye of the dragon-fly, with its myriad of facets, admirable, also, the far-sighted eye of the hawk but what compared with the eye of man, naturally focused on infinity, but capable of use for hours at a time at the shortest distances, and then ready to gaze at the stars again? It is not only something of all the instruments we have named, but it is something of a spectroscope as well, and has no rival in the living world for discernment of color-differences. The optician can construct a spectroscope which analyzes light better, but will he also contrive to give it the properties of a microscope, a telescope, a photographic plate, and a cinematograph into the bargain?

The sense of smell that has given way to the sense of hearing and vision

We might consider the other organs of sense, and make similar observations, but let us notice the nose alone, and mark the conspicuous inferiority of smell in man.

The organ is there, as in other animals, and with nothing more to remark as out of the way than we find elsewhere in man's body. But when we observe it more closely, we find it positively degenerate. Man cannot be bothered with it. Such a sense, highly specialized for use along with taste, at short distances especially, is all very well for creatures which work at short distances, and, in another use, for creatures which live by hunting prey which they must scent. Man, the ubiquitous, omnivorous, creative, will not burden the precious interior of his skull with the large nervous centers necessary for the full development of such a sense. He needs more room for senses like vision and hearing, which his mind can employ in speech, the all-adaptable, and so the olfactory nerves get scant space.

Hence, the general facts of man's body are largely negative. Apart from its erect attitude, it is an unremarkable body, mechanically and superficially inefficient. Endow it with any brain less than man's, and he would, without any doubt, quickly become extinct.

The efficiency of man's brain that makes up for his physical deficiency

Apes, however, are fairly covered with hair, which is an immense protection to the skin from all manner of risks — dirt, light, scratches and many more. Man has not even that. As if in bravado, or to show plainly what his principles are, he has even divested his body of its coat of hair, and prefers to clothe it with what his brains enable him to take from other animals, or what they make from the products of the vegetable world. He is a creature whose first home may have been tropical or semi-tropical, but he set out to conquer the earth, from the equator to the poles, and began his journey to colder climates minus a noticeable coat of hair. This paradoxical fact is highly typical of man's body, in its deepest as well as its superficial aspects.

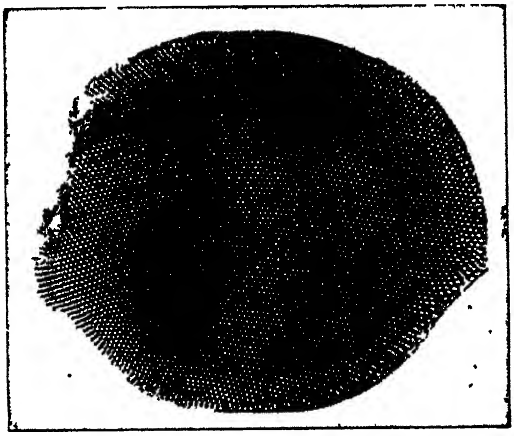
When we come to study his instincts and intelligence we shall find how deep this principle has gone. Other creatures have specific instincts, adapted to their environment, and to no other, just as they have specific structures for single purposes.

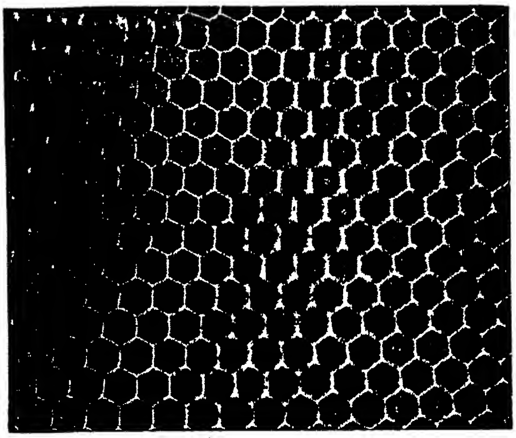
The ever-growing intelligence that has supplemented human instinct

Man, for his part, has shed these specific, rigid, within their domain perfect, but uneducable instincts, and threatens even to shed his teeth, because some drastic physicians attribute all diseases to them. Such instincts would get in his way, just as fine birds' wings for flying, at the cost of his fingers, would lower instead of raise him. In the domain of mind we find that the rigid, limited instincts of his ancestors, perfect for their purpose, worse than useless in any new situation, have yielded in the main to something called intelligence, which knows nothing "by nature," requires to learn, and takes a very long time about it. But intelligence knows no limits; it can employ man's no longer rigid but plastic instincts, it is capable of adapting itself to all possible conditions of existence, and of adapting the outside world to itself.

Thus we see that this unique being, made of body and not-body, is consistent throughout. In other aspects of his being he is at first sight particularly undistinguished, and that is why he can distinguish himself in every possible sphere, and beat every animal at its own game

Again, how much more clearly is the paradox pointed when we look at the body of man in its infantile state! If it is open to criticism when mature, it is simply ridiculous, if not pathetically helpless, when immature The human baby is the most helpless of living things, and will be lord of the earth It is helpless in body, and all but helpless in instinct. Its intelligence shows not a trace of its coming, and while its body is not adapted for anything but the erect attitude, it is yet many months short of being adapted even for that. But this naked, helpless object, ridiculous from the mechanical point of view, since its balance is so defective, and no less ridiculous from the point of view of instinct, or of muscle, or of sensation, is so exactly because it is preparing for a universal conquest, and must not allow itself to be led into any narrow rut at the start.





TWO REMARKABLE PHOTOGRAPHS OF A BEETLE'S EYE

The left photograph gives the whole eye of a beetle, the right a small part more highly magnified, showing the facets of which it is composed Such an eye as this is in many ways more wonderful than the human eye, it is highly specialized and consists in reality of thousands of separate eyes But while the human eye cannot claim such high specialization as this of the beetle, it has properties infinitely more wonderful The human eye is imperfect as a telescope, imperfect as a microscope, imperfect as a camera obscura, but it is something of all these

Every other living creature is in such a rut. Their brains may grow somewhat larger, bones stronger, leaves greener, but in every case all has been staked upon one limited possibility of environment. Man alone has traveled the open road, and, while he has sacrificed nothing vital, has lost and continues to lose whatever is not worth his while on this endless journey Other creatures find a niche in the world, fit themselves, and rest and are thankful But it is the splendid attribute of man that he never is, but always to be, blest No niche in the world is good enough for him. He proposes to remake the world, and does so at this hour — severs continents, creates new chemical compounds for his protection from microbes, builds cities, and so forth.

The body of man is an animal, but it belongs to a creator, and it is the body of a creator, who accepts it not as a finished or final product, but as an instrument of his creative purpose. The great artist requires a simple instrument, adaptable to any purpose — a pencil which can write a sum in addition or an epic, a chisel which can carve a mantelpiece or a Madonna, an alphabet and a scale which can make all language and all music.

Just so is man's body the simple, all-capable, adaptable, limitless instrument of the creative artist, who looks upon the earth and upon himself, and finds neither wholly good. But he is now steadily, very slowly, but very surely achieving with this strange new-old instrument of his, which we call the body of man, the purpose of the mind of man, which is to take the world without and the world within, and remold it nearer to his heart's desire.

"A FAVORITE CUSTOM" — FROM THE PAINTING BY SIR LAWRENCE ALMA-TADEMA, R A.

The baths of the Romans were probably the largest and most luxurious in the world's history, some of them having a capacity for three thousand bathers. A perpetual stream of water was poured into the capacious basins through the wide mouths of lions of silver. "To such a pitch of luxury have we reached," says Seneca, "that we are dissatisfied if we do not tread on gems in our baths."

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BATHING AND SWIMMING

One of the Imperative Decrees of Health and the Art that brings Us Back to Nature

HOT AND COLD, FRESH AND SALT WATER

SINCE all life is lived in water, as we know, and since it is certain that the body is always losing water, a new supply is always required, especially as our power of storing water is very small, and disastrous consequences follow when we store more than a very limited quantity Our needs in this respect are shared with all forms of life, but we further resemble other high forms, such as trees, in that we no longer take water in at all points, but only by a special channel The tree is rained upon or we may be drenched to the skin, but neither of us takes in one drop of water in consequence

First of all, therefore, we must study the laws of health in regard to external water — water which never enters the body at all, but may affect it We have only to remember the mysterious company of ailments conveniently, and ignorantly, called "rheumatism," and their connection with damp states of the air or of one's clothes, to see that water outside the body may affect it no less than water inside it.

In all the air we breathe there is water-vapor, as one of its normal gaseous constituents, and this we take in with the rest But as we always give out more, in each breath, than we took in, evidently the body receives no water from the inspired air. It does not follow that the water in the air is of no consequence. On the contrary, its quantity affects us deeply. Strictly speaking, what matters is not the quantity of water in the air, but the proportion of it, in comparison with what the air can possibly hold. The warmer the air is, the more water it can hold; and a warm air may thus contain far more water than a cold.

But the thing that matters to us is that the cold air, perhaps, is filled with water, or saturated, whereas the warm air, though holding far more, has not exhausted its capacity We therefore require to introduce the idea of a relative humidity of the air to express its proportion of actual to possible moisture at any given temperature

This question of relative humidity is of unceasing importance to the meteorologist, who is constantly concerned with the instruments that register it, and finds its consequences everywhere But we have now learned that it is of no less importance in matters of health. The body must continuously lose water if it is to live, the process is exactly and entirely as essential as the need for the continuous intake of water. But while the task is largely undertaken by skin and breath, and is easy and rapid when the relative humidity of the air is low, of course it is hampered when the relative humidity is high.

Within the last few years experiments have been carefully repeated, under the supervision of the most competent medical experts and scientists, which prove conclusively, by exact observation on man, what has hitherto been only presumed. We now know that one of the chief causes of fatigue, headache, depression, lack of appetite and subsequent anæmia, following exposure to confined air, is the fact that such air soon gets loaded up with moisture, and then retards our loss of it. The subject is so important, and will require to play such a part in future reforms of housing and ventilation, that we must return to it again and again

Meanwhile, we note that, while no water from without really enters the body by the lungs, any more than by the skin — both being organs for getting rid of water — it matters immensely that we live in an atmosphere which contains water, and our health cannot long be maintained in any atmosphere which contains such a proportion of actual to possible moisture that our getting rid of water is too much retarded.

But when we think of water outside the body, we naturally turn to washing, and there we may continue, though carefully remembering that the body has an inside as well as an outside, and that water is needed inside as well as outside for the elementary purpose of cleanliness

The matchless waterproof material which admits water one way only

The skin is absolutely and at all points waterproof One could not otherwise survive a bath. The appearance of water-logged skin, water-logged from within, is characteristic and tragic Not only need we not fear such results from exposure of the skin to water, but we must not hope to absorb either water, or any salts or tonics, or drugs or foods, dissolved in it, by means of the skin. Sea baths or medicated baths may or may not be useful, but we are definitely to abandon the notion that any of the contents of the water enters the body.

It is only by means of an electric current, specially applied, that we can persuade medicaments or foods dissolved in water to enter the body It follows that any possible results of the use of such special waters must follow from their action upon the skin and its nerves, from without. The skin is not less perfectly waterproof in the inward direction than it is perfectly permeable to water in the outward direction.

We may confidently say that modern knowledge of the body and of disease has not robbed water of its place; and that if we all remembered that nothing dissolved in water enters the body through the skin, we should be better prepared to spend our means wisely when in search of health.

The right kind of exercise that a morning bath affords

To begin with, it is good to wash because it is good to take exercise This is a sensible kind of exercise, just sufficiently interesting to the purposeful mind It involves much variety of movement In the course of washing, the skin is rubbed and massaged mechanically, quite apart from the action of the water upon it This exercise is reasonable in the morning, for it is not too much strain upon the nervous system, which takes many hours really to wake up and be at its best; and also it is a tonic, and helps the nervous system to bestir itself But if the action upon the skin is really to be tonic, it must be induced in the right way. We want the skin to have its circulation improve, but by no means to become congested; we want its nerves to be stimulated, but not to be made irritable and over-sensitive If we use too hot water, or do not take care to neutralize its effects, the result will be to cause the blood-vessels in the skin to relax, the nerves to send messages of slackness to the brain, and to deprive the vital organs of blood by diverting so much of it through the channels of the skin

The right kind of feeling to have when leaving the bath

What exactly will have the good effect and what the bad in any given case, only the person in question can decide. But the upshot of the washing, looked at from this point of view, must be to leave the skin cool, braced, perhaps glowing, but *also* cool, in the delicious fashion so familiar to everyone who has taken a bath of the right kind. That is the vital reaction; and if one does not get it, a change must be made until one does. But to take a bath of any kind, at the end of which one is hot, perspiring and sleepy, is absolutely wrong in every case, however clean it may have made one, except only when sleep is needed and bed promptly sought. Healthy people should not require to aim at this warm, lax condition of the skin, because it should come when we grow normally sleepy.

THE GREATEST VIRTUE NEXT TO GODLINESS

FILTHY DIRTY RUSSIAN PRISONERS FRESHLY CAPTURED BY THE GERMANS

THE SAME MEN AFTER BEING SCRUBBED, DISINFECTED, BARBERED AND GIVEN CLEAN CLOTHES

Therefore such kinds of bathing are to be looked upon as medical, though nothing but ordinary water be used and are to be regarded by healthy people as medicines. And just so soon as the sleep is restored, and the undue flow of blood to the brain is no longer a bad habit at bedtime, but has been broken by the bath, just so soon should this kind of bath be modified — as the doctor modifies his dosing with an opiate as soon as the patient can sleep without it.

If the hot bath is taken in the morning, it must be so taken that one does not leave the room hot and perspiring. We must let cold water run in, or have a shower, or not have the bath so hot to start with, or not stay in so long, but somehow we must contrive to leave the room keener for the day than when we entered it.

The hot bath taken for cleanliness and the cold bath for tonic

In general, the hot bath is better at night than in the morning, but even at night it must not be excessive. It has further advantages at night, in that it is more cleansing than a cold bath. It should always be brief, the hotter the briefer, and on the whole it is not to be named as a means of health compared with a bath which is fairly warm, but not what we should term "hot."

Hot water has enormous advantages for washing with if it be properly used. It is the rule that the body fats and oils are just between liquid and solid at the temperature of the body. Hot water liquefies those which have passed through the skin, and those oils also which we get from the soot of city air. The stimulation of the nerves by heat is good if it be brief, and especially if it be followed by cold. One of the recognized methods of encouraging the breathing of a new-born baby which is not doing well enough in this respect is to apply hot and cold water alternately to the skin. For other people hot first and then cold is the right sequence. If one were to bathe twice a day, the hot bath should be the cleansing bath at night, and the cold bath should be the tonic bath in the morning.

Hot water should be cautiously used for the skin of the face, which is very thin, and the nerves of which are very numerous and sensitive. Many women use very hot water frequently for the face, because of the perfect cleanliness which it alone makes possible, but they should beware of dilating the blood-vessels of the skin beyond the point at which they quickly and entirely return to their former size. Any one with a tendency to a red face, or a red nose in particular, should avoid using any but lukewarm water — and cold water, of course — for the face, and should beware of hot baths, with their obvious tendency to increase the quantity of blood in the skin.

The cold bath in the morning is a standing English tradition, and has been praised and practised far beyond its unquestionable merits.

The test of the cold bath is in its consequences. The elderly and the very young stand cold badly, and react to it imperfectly — which is another way of saying the same thing. The strong and those in general who are not at the extremes of life are caused by the cold to produce more heat than ever, reacting to it as a highly bred horse to the flick of a whip, or as an orator frequently reacts to a great occasion.

The exposure to cold that produces more heat and more energy

It can be experimentally shown that exposure to cold, which necessarily deprives the body of heat very rapidly, soon thereafter causes the production of more heat and more energy, which are duly supplied, in their turn, by a marked increase in the appetite and speed of digestion. This is simply one of the countless cases where the body is induced to call up its reserves, by being somewhat attacked from without.

Mere vaccination induces so much resistance that one defies smallpox, though the vaccination merely called upon one to defy vaccinia or cowpox. And here exposure to a little cold induces a reaction which would enable one, if necessary, to withstand far more.

Now it takes only a very short time for the body to react to cold This must be so, for the attack of cold is immediate, we begin to be chilled instantly, and should soon succumb if the compensatory process did not begin at once, and then it will continue long after the immediate necessity has passed, just like the immunity after an attack of scarlet fever Since the reaction is so quick, it follows that the exposure need not be long How long it should be will depend upon the individual For each of us there is a degree of exposure which will produce the most reaction, and degrees beyond that which will produce less and less, until at last the reaction fails

The vital reaction of the body that takes place after bathing

The problem for each of us is to find the right point, and not to exceed it One should stay in a bath just so long as suffices to produce the most pleasant, warm-cold glow thereafter, and the best vigor for the rest of the day Generally speaking, those who employ cold water at all for these purposes tend to overdo it. For they seem to think that, if half a minute does them good, five minutes will do them ten times as much good, just as people think also about the quantity of exercise which should be taken.

They are quite wrong; the reactions of the body are not mechanical or mathematical, but vital; and they cannot be measured on such simple reckonings as these. Indeed, the proposition has been laid down that the value of a cold bath is in inverse proportion to its length; and though that is, of course, not strictly accurate, and ignores the particular behavior of the individual case, it is so nearly true that it may be usefully remembered. The vigorous and mature may forget it, but directly we have to deal with the elderly or with the young we must remember it. If we do not, we had better avoid any cold bathing for them at all; but if we remember that it is good for them, but the less they have the better, then we may usefully employ this magnificent natural tonic at any age whatever.

The beneficial effect of cold sponging and cold applications in fever

Though we may be inclined to suppose that when a man has fever he is least able to endure exposure to cold, and should be tightly wrapped up, according to the appalling medical practice of not so many years ago, the fact is that fever is just the condition in which exposure to cold can be borne, and may often save the patient's life, by lowering his temperature in the safest possible way Cold sponging, cold bathing, the "cold pack," and other forms of employing ice itself, are the recognized and best methods of reducing many kinds of fever Obviously it is one thing to lower a normal temperature to five degrees below normal, and another to lower to the normal a temperature which was five degrees above it The former is a departure from health, the latter a return to it

The danger of the sponge, and the care with which it should be used

The massage and friction of the skin which naturally go with most forms of bathing have already been praised The stimulation of the nerves of the skin is very useful, alike to the skin itself and to the brain Further, the friction is itself cleansing, quite apart from either soap or water, for it removes the old and inevitably dirty layers of skin which lie nearest the surface of this body covering.

The value of the nailbrush not only for nails but for the whole hand has been proved long ago by surgeons, who know that this employment of it is an essential preliminary to true cleansing of the hands. The use of rough gloves in the bath, and of similar rough substitutes for sponges, is to be recommended

Surgeons do not now use sponges, for they know that they are incapable of real cleansing or disinfection. They use instead swabs, which are only employed once. Doubtless we may freely continue to use sponges in ordinary life, but we should be scrupulous about their cleanliness, and they should be the property of only one person, and used by no one else.

Scrubbing of the skin can be very much overdone The outer layer of the skin exists for the necessary purpose of protection. If we rub it away, or reduce its thickness unduly, we simply expose the really living layers of skin that lie below. This point especially applies to the face The skin is here very thin, and unfortunately the face is much exposed to dirt in the air of modern cities: but it can be cleaned without the use of hot water, or scrubbing, or even soap

The harm that may result from the wrong use of soap

Not that soap is to be underrated as a means of cleanliness Very largely it acts by helping to dislodge and loosen the outer cells of the skin, already ripe for detachment, and thus soap and scrubbing have just the same effect. Also soap acts chemically by dissolving the fats and oils of the skin, and carrying away the dirt which naturally sticks to and lies in these fats and oils There is also an action of the suds, which is not chemical, but seems to depend on making an "emulsion" of the skin-fats, and so getting them away. These actions are best displayed in an alkaline soap, and there are very few soaps which do not contain a quantity of free alkali on this account, especially as the value is no less for clothes than for the skin But the skin is unlike any piece of cloth, in that it is alive, and it is apt to resent the use of alkalies, if they be of much strength It is better to use, for delicate skins, soaps which have been prepared for the purpose, such as "super-fatted" soaps, which contain free fat and no free alkali. No soap containing free alkali should be used for the thin and sensitive skin of the face, but only a mild, non-alkaline soap which acts in the third of the three ways we have noted, but not in the other two It must be remembered that soap is a human invention, and that skin is not. The skin has its own power of cleansing itself, as no lifeless surface has; and if it be reasonably helped it is more likely to remain well and clean than if it be treated as if it were an inanimate thing like a metal plate.

The best possible kind of exercise that we can take in water

Obviously our first principles are all unsound if bathing in the open air is not far superior to anything indoors All the arguments in favor of the open door, even beyond the open window, apply here, as to every form of exercise, game, or sport. The value of moving air is closely similar to that of moving water — moving because it is in a stream or on a shore, or because we are moving in it, which comes to the same thing so far as the action on the skin is concerned We ought to aim at personal movement, in water, whether indoors or out, even more than at personal movement in air, because water is colder, being a good conductor of heat away from the body, which dry air is not The best bathing, therefore, is swimming, and of all the uses and applications of water outside the body, ordinary or medicinal, there is none so good, so natural, so free from drawbacks, or so various in its utility to mind and body, not to mention the lives of others, as we obtain in swimming.

Normally and naturally we associate swimming with the open air This is not to say that swimming in an indoor pool is not well worth while Its only superior as an exercise is swimming in the open air, and that is very high praise indeed Much improvement has been made in recent years Some day we shall have all children taught to swim At present our attitude toward the matter is made evident by comparing the population of any of our great cities with the number of its public swimming pools.

The covered pool has many distinct advantages for the learner, it is invaluable in a cold climate during quite half the year, and there are many people who react so inadequately to cold water that their stay in sea, pond or river must be so brief as to prevent them from really getting any swimming exercise. For them, evidently, the ideal is the indoor swimming pool, the temperature of which they can, perhaps, comfortably stand for any thing up to half an hour, and after which they will get a good reaction, though never the perfect reaction which comes from open-air swimming.

Fresh water as well as salt water bathing possessed of many virtues

Open-air swimming may be in still salt water, still fresh water, streaming fresh water or the sea. Open-air salt water baths, as also closed ones, have the advantage of the salt, which is real, but have the disadvantage that the water is still. The swimmer and the diver compensate for this by producing movement of their own, thus getting both the salt and the friction. Fresh-water bathing has its virtues, and many a child may be safely taught to swim in a pleasant stream, lake, or pond.

The best bathing of all — not, of course, for all, but for most — is sea bathing. This being the experience everywhere, and its saltness being the most notable characteristic of sea water, after its wetness, we may abstract the salt, if we will, and add it to our baths. The results are not the same. Those who like to add salt to their baths are not here advised to discontinue it. They may be right — right in general, or right for them. But anyone who supposes that it is the saltness of the sea that matters in sea bathing is mistaken.

When sea bathing may prove to be wholly injurious to the bather

Let us remember that none of these salts enter our bodies through the skin — not to the extent of a single molecule. They may enter by the mouth, but this method of administration is not favored by the experienced, even though the internal value of salt water may be very great. The total action of the salt is entirely upon the skin, not through it; and, as our skins tell us, that action must be small, for we notice little or nothing. If the salt were allowed to remain, as by putting our clothes on while we were wet, there might be more results, perhaps; but we do not need to look far to realize that it is the total effect of the bathing that really matters.

The proof of this is furnished at once by the tired, unwilling, frightened or even unaccustomed solitary bather. The sea is as salty as usual, the water may be warm enough and the sun shining. Yet in such cases the bathing may only do great harm. A bather who knows no such thing as indigestion, may find himself promptly rejecting his next meal, simply because he has shocked his nerves into erratic action. The frightened child may have night-terrors or suffer from nervous shock. The young girl may have important bodily functions interfered with, or arrested. Such and many other consequences may follow from sea bathing that is ideal in every respect but one, which is that the mental factor of success is lacking.

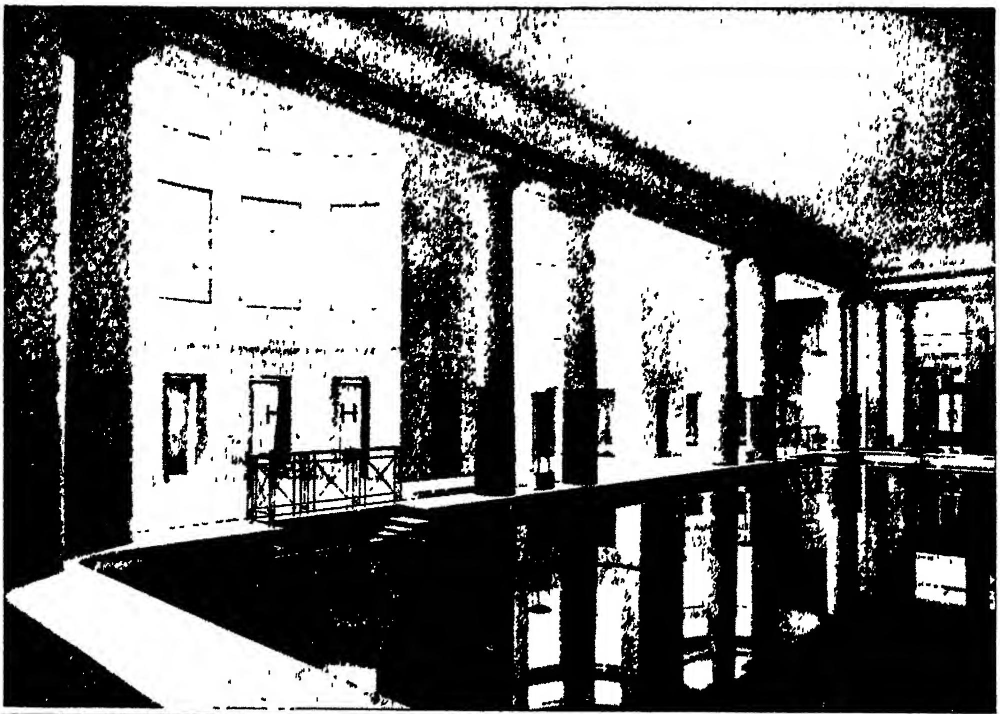
The unique combination of factors which makes the virtue of sea bathing

Many people are only slightly sensitive to this factor, and some are exceptionally sensitive, but though we vary, the fact remains that the real virtue of sea bathing at its best, which has restored so many people to life and health and usefulness and beauty, depends upon the extraordinary and indeed unique combination of factors with less than which we should never be satisfied, for ourselves or for those whom we love. It is against the forgetfulness of this truth that we protest when we criticize the employment of sea salt in the bath water as a substitute for the light and air and sand and swimming and waves and company and sense of strange return to something natural but unknown or unaccustomed, and joy in skill and courage, which belong to bathing in the surf, and to that alone.

The vital factor which must be present before we bathe in the sea

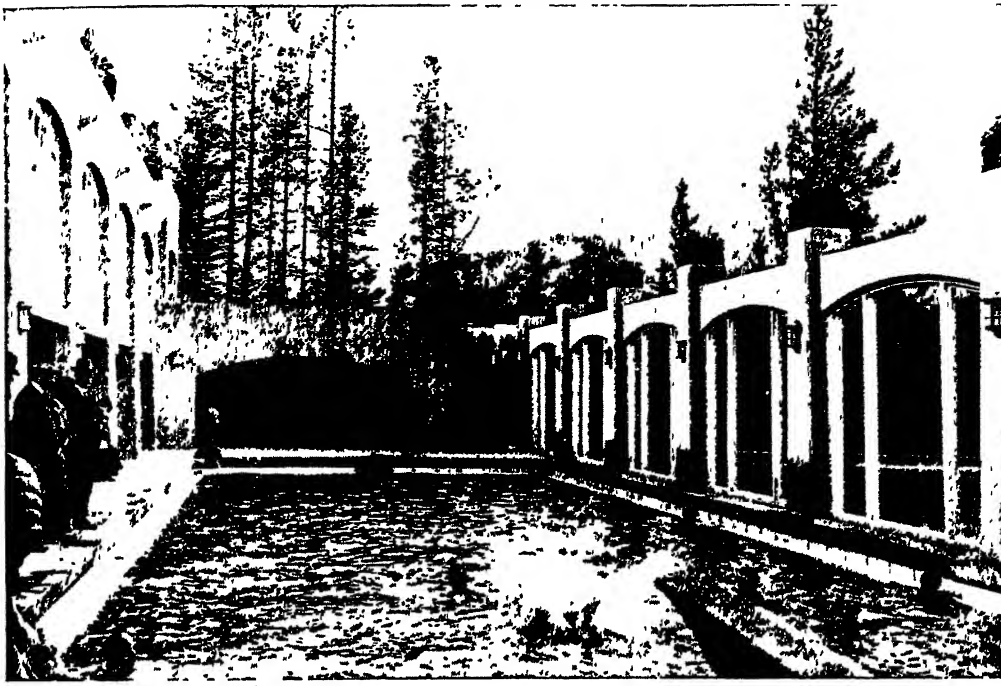
Man is not a body, nor is he a mind. He is both. They move together, act and react on one another. Water, labeled "morphia," injected under the skin, will often relieve severe pain and produce sleep. Salt in one's bath, if one believes in it, may be precious, for memory's sake and for its influence on mental expectation. With a creature so complex as ourselves, and compounded of such utter opposites as body and mind, all things, or nearly all things, are possible. But what is not possible is to understand the influence of anything upon such a creature unless both mind and body be taken into consideration.

INDOOR SWIMMING POOLS



Within the last few years considerable attention has been paid to the provision of suitable indoor swimming-pools, and these photographs show the luxurious pool of the Royal Automobile Club in London.

From photographs by Bedford. Lemere & Co.



Courtesy of Canadian Pacific Railway

Outdoor swimming pool at the Banff Springs Hotel, Canadian Rockies This is the warm pool (supplied by a natural hot spring) To the right, through the arches, is the cold pool

© Brown & Dawson

Swimming pool at Colon, Panama, in front of the Washington Hotel.

There are those who impose such things as sea bathing upon themselves or others, and especially the young, without seeing to it not only that the sun is bright as the child goes in, but that the child's eyes are bright as well. It is cruel to a child or a convalescent to prescribe treatment of such a kind, when the vital ingredient, which is called "happiness," and is not stocked at ordinary pharmacies, has been left out; and not only may serious injury be done at the time, but a permanent distaste may be given for what is perhaps the finest and most delightful exercise in the world. It is not funny to be frightened in the water, to swallow salt water, and to feel no bottom under one's feet when one cannot swim, or has only just learned. To discuss the salt's action on the skin, or the sun's action upon it, and omit such considerations, is to have pierced no further than the skin of this subject.

The value of the sun's rays on the surface of the skin and its deepest workings

No doubt the exposure of the skin to the sun's rays must be of importance in such sports as sea bathing, and it may briefly be referred to, though our subject is water, for the two should go together. In recent years sun baths have become fashionable, and there are many places abroad, and even one or two in this country, where arrangements are made for people to expose practically the whole of the skin to the sun's rays, even for hours at a time. There are many factors in this question, and we are only beginning to learn of them. The composition of sunlight varies in different conditions of the air, and its various components are markedly different in their action upon the skin of the body. When the breathing of some dogs was carefully observed, it was found that they consumed sixteen per cent less oxygen in a given time when their eyes were bandaged, than otherwise. We consume less oxygen during sleep. Neither of these facts is really conclusive, but they suggest what is very probable on other grounds — that the action of light on the body is not only cutaneous (on the skin), but affects its deepest workings.

Nevertheless, there is, at any rate, no doubt for us, in relation to sea bathing, that the sun is of great value by its exhilarating effect, though whether one would not need something more subtle even than the chemistry of oxygen to measure this effect, may well be questioned.

The exercise which brings brain, body and soul into true relation

The *therefore* does not always follow, but neither does the contrary follow — that only what one does not enjoy is useful. The more enjoyable a bath is, the better it is, and though light has often been called the best tonic, it is dull and impotent compared with happiness, which is the best tonic of all for old or young, well or ill. The observation of doctors thus is that sometimes their patients do splendidly under a course of sun baths, and sometimes they go from bad to worse. The evident conclusion is what, indeed, inquiry shows. Owing to the other circumstances of the visit, the one set of patients has been happy, and the others have been unhappy. The wisdom of old has long taught us that a merry heart doeth good like a medicine; it is so true, that the medicine alluded to has yet to be found.

An essential part of sea bathing, looked at from the point of view of health, lies in the ability to swim. Anyone can learn to swim and everyone should. It is not difficult, it is enjoyed by everyone who can do it, and it is the exercise of swimming, and the swimmer's encounter with the water, that give an essential part of its complete value to sea bathing. The exercise is not all, though it is much. Certainly it is quite as complete, as symmetrical — in breast-swimming — and as suitable for the structure of the body as any that can be named, even including walking, for which the body was certainly not designed; but similar exercises in other conditions do not have the same result. It is the mental factor of swimming in the surf that counts; the exhilaration and stimulation and sense of fitness and self-confidence that come from our transient mastery over the magnificent and immeasurable forces that surround us.

COMMUNICATION BY WIRE

The Rapid Transmission of Intelligence across Land and Sea

THE TELEGRAPH AND TELEPHONE

SINCE time immemorial man has used some method of signaling through space. Some of the methods are explained in detail, while others are only mentioned casually in ancient literature. Cyrus the Great is known to have employed a mysterious system of signals by which he could send a message across the Persian Empire in one day, a distance which could not be covered by a horseman in less than thirty days. The Roman soldiers sent signals by moving their shields into definite positions or by flashing them in the sunlight.

The American Indian built a smoke fire on a hilltop and covered it periodically with a blanket to produce a succession of smoke plumes which were translated into words by a distant observer. Biblical history contains many references to smoke signals and it is believed that signals were sent in this manner from the Tower of Babel. Napoleon in his Russian campaign communicated with Paris on clear days by a continuous system of semaphore stations. The semaphore system of communication, called the "telegraph," was in fact developed to a considerable degree throughout France and to a lesser degree in England and Germany.

None of these methods could be employed at night or even in the daytime under conditions of low visibility. When Wellington was fighting in Spain, London was thrown into a panic one day by a semaphore message sent from Portsmouth to the Admiralty which said, "Wellington defeated." Some time later two more words, "the French," came through, having been delayed by a sudden fog at Portsmouth.

Communication at night by flashing lights has been in use for many centuries. It is believed that the Chinese first used the sky-rocket for signaling purposes along the Great Wall as a warning against an impending attack. The same device has been used for many years as a signal of distress by ships at sea. It will be remembered that Paul Revere, in 1775, aroused the minute men between Boston and Concord and told them the message conveyed to him by the signal lamps hung in the belfry of a church. At one time the British Navy sent night signals by raising and lowering a lantern in a bucket.

In many instances when vision was obscured signals were sent by the sound of bells, whistles and even guns. The distance to which signals could be sent directly by any of these agencies was limited by the sensitiveness of the eye and ear and the nature of the intervening obstructions. Only the heliograph or mirror flashing the sun's rays could be employed to signal over distances of several miles. In all other cases the signals had to be repeated from station to station laboriously and under conditions which favored error in transmission.

The fact that electricity could be sent through a wire of considerable length was first demonstrated by Stephen Gray in 1729, but it apparently did not occur to him that his discovery furnished the means for the rapid transmission of signals. The earliest suggestion of the use of electricity in communication appeared in an anonymous letter to the *Scot's Magazine* in 1753. The letter is believed to have been written by Charles Morrison, a Scotch surgeon

Preparing the way for the coming of the electric telegraph

The method which Morrison proposed, like many others which followed it, involved the use of as many wires as there were letters to be transmitted. By charging the wires successively with an electrostatic machine — there were no batteries or dynamos in those days — and causing the respective charges to attract bits of paper at the other end of the line, messages could be sent a mile or two at considerable speed.

The development of the modern electric telegraph from this primitive suggestion required many years of discovery and invention. It was first necessary to provide better insulators for the conductors. The use of glass insulators on wooden poles, as in present practice, was not adopted until 1828. More important still was the invention of the electric battery which could send a steady current through the wires. While the first battery was constructed by Volta in 1800, a battery of sufficient strength for telegraph purposes was not invented until 1836. In the early part of the nineteenth century various inventors suggested electric telegraphs which required only two connecting wires, a marked improvement over the previous systems.

The discovery of electromagnetism by Oersted in 1820 may be said to have been the culminating episode in the development of the electric telegraph. It was well understood before this discovery that various impulses of electric current could be sent over a wire of considerable length, but no satisfactory way had been found to recognize these impulses at the receiving end of the line. Many crude methods had been employed for the purpose. De Salva, a Spaniard, suggested, for example, that a man stationed at the receiving end of the line could hold the ends of the wires in his hands and interpret the message by means of the number of electric shocks that he received.

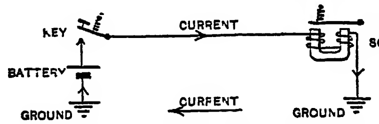
Oersted discovered that a magnetic needle placed near a wire would be deflected when a current was sent through the wire. Ampère at once suggested that the deflection of a magnetic needle might be utilized for the reception of electric signals, but a practical needle telegraph system was not devised until 1837, notably by Wheatstone and Cook in England. Joseph Henry, while a professor at Princeton College, made important contributions to the knowledge of electromagnetism between 1828 and 1831. He demonstrated that the magnetic effect of an electric current could be amplified many times by winding a coil of wire on some soft iron. In fact he explained to his classes the possibility of ringing church bells at a distance with his electromagnet. It is indeed curious that Professor Henry with his unsurpassed knowledge of electricity and magnetism did not appreciate the commercial importance of his electromagnet.

The electric telegraph realized at last as the result of a chance conversation

It would appear that the invention of the modern telegraph by Samuel F. B. Morse in 1837 was instigated by a chance conversation between Mr Morse and Dr. Charles T. Jackson of Boston during a voyage from Havre to New York in 1832. When Morse was required to defend his patents before the Supreme Court in 1850, Dr. Jackson claimed that he had suggested most of the elements of the invention to Mr. Morse during this ocean voyage. Professor Henry also stated that the principles of Morse's invention had been common knowledge before the patent was filed. The captain and fellow passengers on the ship refuted Dr. Jackson's testimony, however, and the court upheld the validity of Morse's patent.

Whether Morse made use of the suggestions of others or not, he nevertheless succeeded by patience and perseverance in constructing an electric telegraph which was better than any other device previously suggested. His first telegraph line was constructed under an appropriation of Congress between Baltimore and Washington in 1844. The principle of the Morse telegraph is similar to that in use everywhere today.

When the key at the sending station is closed, the battery sends a current through an electromagnet at the receiving end, the current being conducted to the electromagnet by a single insulated wire and re-



THE SIMPLE MORSE TELEGRAPH

turning through the ground When current is passed through the coils on the electromagnet, a strip of iron held away from the poles of the electromagnet by a light spring is pulled down with a sharp click. In Morse's first telegraph a pen was attached to the end of the vibrating strip of iron. The attraction of the strip of iron thus caused the pen to make contact with a moving ribbon of paper, drawing upon the paper a series of short straight lines which represented in length the comparative times the circuit had been closed.

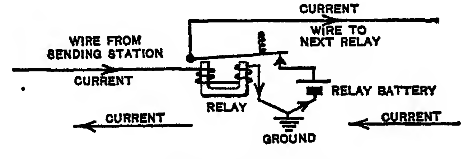
	MORSE	CONTINENTAL		MORSE	CONTINENTAL
A	.-	.-	T	-	-
B	-...	-...	U	..-	..-
C	.. .	-.-.	V	...-	...-
D	-..	-..	W	.--	.--
E	.	.	X	.-..	-..-
F	.-.	..-.	Y	.. ..	-.--
G	--.	--.	Z	... .	--..
H	....	....			
I	..	..			
J	-.-.	.---	1	.--.	.----
K	-.-	-.-	2	..-..	..---
L	—	.-..	3	...-.	...--
M	--	--	4	....-	....-
N	-.	-.	5	---	.....
O	. .	---	6	......	-....
P	.....	.--.	7	--..	--...
Q	..-.	--.-	8	-....	---..
R	. ..	.-.	9	-..-	----.
S	...	...	0	—	-----

MORSE AND CONTINENTAL CODES

The present use of the electromagnet as a "sounder" came about unexpectedly. The operators became so expert in receiving the message by sound that the former printing method was abandoned. The dot-and-dash code invented by Morse, while used commercially through the United States, has proved confusing in the fact that certain letters differ only by the time intervals between the dots, and it is often difficult to distinguish between them. The Continental code is free from this defect and is used generally throughout Europe, in ocean cable telegraphy and in the radio telegraph.

Having demonstrated that the Morse telegraph could be operated successfully between Baltimore and Washington, the line was extended during the next three years to Portland, Maine, and from New York through Buffalo to Montreal In 1848 the entire country had become enthusiastic regarding the possibilities of the telegraph, and lines were projected in every direction. The cities and towns of every civilized nation soon were connected by telegraph, and in 1921 there were over 1,500,000 miles of telegraph line, consisting of nearly 6,000,000 miles of wire.

In a long line the current established in the circuit is inherently weak by reason of the high resistance of the many miles of wire The current, moreover, is weaker at the receiving end than at the sending end because a considerable amount of current leaks from the insulated wire to the ground and returns to the sending end without reaching the sounder. To overcome this difficulty Morse invented relays, or repeaters, which were connected into the lines at intervals. The relay consists essentially of an electromagnet which in attracting its strip of



THE MORSE RELAY

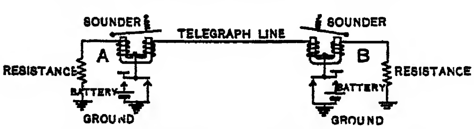
iron connects another battery to the next section of the line. With this addition it will be seen that the message may be sent on indefinitely.

Speeding up the traffic

Messages may be sent between two stations by experienced operators with the simple Morse telegraph at a maximum rate of forty five-letter words per minute

Courtesy American Telephone and Telegraph Co
SAMUEL F B MORSE

When the traffic per wire exceeds this rate either the number of wires in the telegraph line must be increased or some method must be devised for increasing the traffic that may be sent over one wire. Since the construction of telegraph lines is expensive, it is more economical to install apparatus at the ends of each line which will permit of greater speed in transmission.



THE DIFFERENTIAL DUPLEX TELEGRAPH

Duplex telegraph systems, by means of which messages may be sent both ways over a single wire at the same time, were suggested as early as 1853 and were put in commercial operation in 1868.

In the differential duplex system the operator at *A* in depressing his key sends an equal amount of current in both directions from the central connection in his sounder. His sounder, therefore, will not operate, but the current sent in one direction only through the sounder at *B* will cause it to operate. The operator at *B* in the same manner can send a message simultaneously to *A* over the same wire A quadruplex telegraph system invented by Thomas A Edison was placed in operation in 1874 and provides for the simultaneous transmission of four messages, two in each direction, over a single wire. Some form of quadruplex system is employed on most telegraph lines today. A sextuplex system, transmitting three messages in each direction simultaneously, has been devised but is not in common use.

Another method which permits six messages to be transmitted in each direction at the same time involved the installation of two revolving contact wheels which turn at the same speed at each end of the line Each operator is thus connected to the line and to the corresponding sounder intermittently through similar contacts on the revolving wheels. By this system 200 words per minute may be sent simultaneously in each direction, and it represents the maximum speed of transmission for a telegraph system operated by hand.

The increasing use of the electric telegraph for the transmission of long press dispatches led to the development of automatic systems by which a speed of 400 words per minute in each direction can be maintained over one wire. In most of the automatic telegraphs in use today the message to be transmitted is prepared in advance by operating the keyboard of a special kind of typewriter which perforates the dots and dashes in a paper ribbon which runs through the machine. When completed this ribbon is passed rapidly through a sending machine which produces the corresponding pulsations of current in the telegraph line. At the receiving end the message is taken down on a moving tape, either in similar dots and dashes, as in the original Morse telegraph, or by a printing machine which translates the pulsations of current into letters and prints them on a tape.

A modification of this method is found in the "ticker" telegraph system by which an operator in a stock exchange manipulates a keyboard and by telegraph connection prints stock quotations on paper tapes running through printing machines in the offices of stock brokers in many cities simultaneously

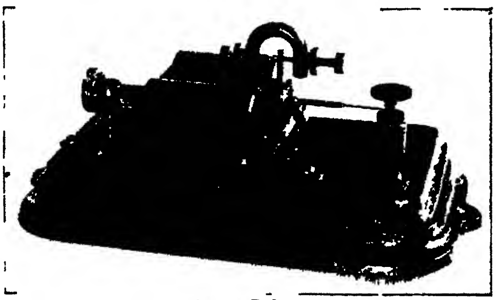
Other applications of the telegraph

An instrument called the "telautograph" extends the telegraph principle to the reproduction of handwriting at a distance At the receiving end the handwriting is written on paper by an electrically driven pencil as fast as it is written with a similar pencil at the other end of the line Various methods for the electrical transmission of pictures, called "telephotography," have also been developed to a considerable degree of perfection In each case a small beam of light is sent successively through each element of detail of the picture to be transmitted. The intensity of the light transmitted through the picture at any point depends upon the degree of light and shade at that point. This transmitted light when striking a small strip of selenium changes its electrical resistance, the stronger the light the smaller the resistance of the selenium Successive pulsations of current may thus be sent over a wire to a receiving device, where the original picture may be reproduced, point by point, by the varying chemical action of the current on sensitized paper. One system has been invented in which the picture may also be reproduced in its original colors. Numerous systems of television, depending upon the same property of selenium, have been constructed and enable one to see all parts of an object simultaneously through the agency of connecting wires. In one instance it was possible to see simple geometric patterns exhibited seventy-two miles away.

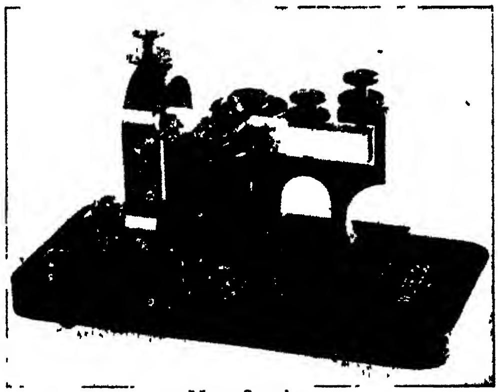
The fire-alarm telegraph enables us to pull down a hook at the nearest fire-alarm box and notify the fire department of the existence and approximate location of a fire. In the automatic fire-alarm system the heat of the fire itself causes the sounding of the alarm.

Time signals are sent out daily at noon to the principal cities from Washington, and clocks which may be running fast or slow are corrected by telegraph On both steam and electric railways the telegraph has played an important part in preventing accidents and maintaining continuous service The railway block signal system conveys information by colored lights or

Morse Key



Morse Relay



Morse Sounder

Courtesy Western Union Telegraph Co

FAMILIAR TELEGRAPH INSTRUMENTS

the positions of a semaphore arm as to the condition of the track ahead of a train. While these signals in most cases are set automatically by the motion of the trains, they are often under the distant control of a train dispatcher. Even the common door-bell is but another simple application of the telegraph principle, further elaborated in the hotel annunciator.

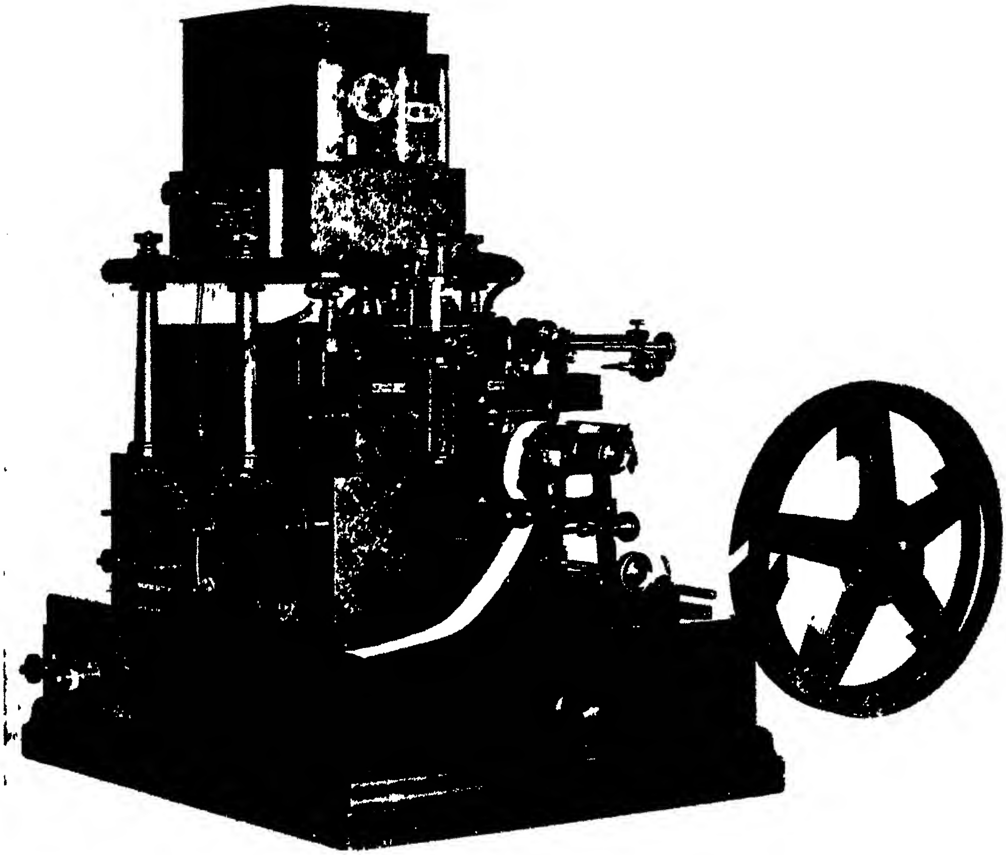
The ocean telegraph

The transmission of telegraphic messages by submarine cable across an ocean involves far greater difficulties than those encountered on land The cable itself is laid and maintained with great difficulty and expense Every inch of the internal copper wire must be insulated perfectly from the salt water which surrounds it Its operation is more sluggish than in the land line. In the latter when the key is pressed the current increases rapidly to its full strength in all parts of the line at practically the same time. In the submarine cable the current rapidly rises at the sending end, but may take more than a second to reach the same magnitude at the receiving end two thousand miles away Moreover, the relay which is utilized to strengthen the signal at intervals on the land line cannot be connected into the submarine cable for obvious reasons.

While others had suggested the use of submarine cables in telegraphy and a successful cable was laid in 1846 between England and France, the credit for the accomplishment of an Atlantic cable is due primarily to the indomitable spirit of an American, Cyrus W. Field (1819–92) It was after his retirement from active business at the age of 33, with a large fortune, that he met the Canadian inventor and electrician Frederick N. Gisborne (1824–92), who had just laid the first deep-sea cable in American waters, between Prince Edward Island and New Brunswick, and planned to connect Cape Ray and Cape Breton. Becoming interested in this scheme, Field considered the time ripe for a greater one — a transatlantic cable. In 1856 he organized the Atlantic Telegraph Company, supported almost entirely by English capital. With an English and an American warship he attempted in 1857 to lay a cable between Ireland and Newfoundland. The cable parted 335 miles from the Irish coast and was abandoned Another trial was made in 1858, two warships starting in mid-ocean and paying out the cable as they sailed in opposite directions toward Ireland and Newfoundland. After the cable had broken several times, the vessels returned to Queenstown Later in the same year the warships started again in mid-ocean and the cable was laid without accident On August 7 1858, the first signal was sent from Newfoundland to Ireland, but the cable failed on September 1, 1858, and was abandoned with great financial loss to its promoters

Another cable laid in 1865 broke at a distance of 1200 miles from Ireland and could not be recovered. The next year a new cable was laid successfully, and the cable abandoned in 1865 was picked up and completed One of these cables failed in 1872 and the other in 1877, but four other cables laid in the meantime continued in service In 1921 the various parts of the world were connected by 530 ocean cables with a total length of 242,000 miles.

The feeble nature of the signals sent through a long cable necessitated the invention of more sensitive receiving devices. The siphon recorder, invented by Lord Kelvin in 1867, is employed almost exclusively for this purpose today. This instrument consists of a light coil of fine insulated wire suspended between the poles of a powerful magnet. When current from a cable is sent through this coil, it twists one way or the other, depending upon the direction of the current. A thread attached to one corner of the coil pulls a tiny glass tube containing ink back and forth across a paper tape which moves slowly under it. The other end of the glass tube terminates in an inkwell placed higher than the paper, so that the ink is conveyed to the paper by the siphon action. The current is sent from the sending end of the cable in one direction to represent a dot, and in the reverse direction to represent a dash. When the waving line traced upon the paper passes above the horizontal line it is recognized as a dot and when it passes below as a dash, the Continental code being used exclusively. The speed of sending has been increased by a duplex system which permits two messages to be sent, one in each direction, at the same time. It has not been found possible to adapt any of the faster systems of the land line to the ocean cables.



Courtesy Western Union Telegraph Co

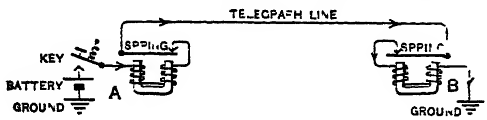
SIPHON RECORDER

This sensitive instrument records on a paper strip graphically by a wavy line the message sent over a long submarine cable. A wave to one side of the middle line represents a dot and to the other side a dash

Talking through a wire

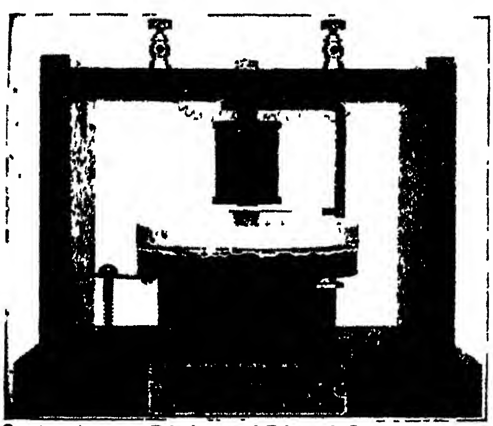
A few years after the introduction of the telegraph, it is reported that the operators amused themselves when business was slack by beating the time of the popular songs of the day with their telegraph keys. Many of the operators became so expert in this pastime that the song was easily recognized by the corresponding beats of the sounder at the other end of the line. In 1854 Charles Bourseul, in France, suggested that a diaphragm be connected to one of a pair of contacts in a telegraph line so that the vibrations of the diaphragm in opening and closing the circuit might produce pulsating currents in the line of the same frequency as the sound waves which fell upon the diaphragm. He furthermore explained that a similar diaphragm placed near an electromagnet at the other end of the line would vibrate by magnetic attraction and reproduce the original sound. No practical application of this idea was developed, but in 1861 Philipp Reis, in Germany, constructed an instrument which accomplished practically the same purpose. Reis called his instrument a "telephone" and succeeded in transmitting musical sounds with a fair degree of success, but his speech transmission for the most part proved to be imperfect. It will be seen from the later development that a minor alteration in the Reis telephone would have made it operate perfectly. In 1885 a monument was erected to the memory of the inventor in his native town of Gelnhausen.

In 1871 Alexander Graham Bell, a professor at Boston University, became interested in the study of multiplex telegraphy, a popular subject at the time because of the rapid development of the telegraph industry He conceived the idea of sending several messages over a single wire by means of a number of pairs of steel springs. The following brief explanation of Bell's harmonic telegraph is given because it represents an important link in the development of the telephone.



BELL'S HARMONIC TELEGRAPH

When the key is closed at *A* the sending spring is attracted by the electromagnet, but in moving breaks the circuit so that the spring will vibrate continuously at its natural frequency while the key is closed



Courtesy American Telephone and Telegraph Co

MODEL OF PROF. BELL'S FIRST TELEPHONE

This is a duplicate of the instrument through which speech sounds were first transmitted electrically in 1875

Since the current in the telegraph line pulsates at the same frequency as the vibrating spring, another spring at *B* at the other end of the line with the same frequency of vibration, will be attracted intermittently by the electromagnet. It is thus possible to make two similar springs vibrate in unison at the ends of a telegraph line. Bell believed that a number of these units could be connected to the ends of a single telegraph line and that several messages could be sent at the same time if each pair of springs was tuned to a different frequency of vibration Although he built several models of this type of multiplex telegraph he was never able to make it work satisfactorily.

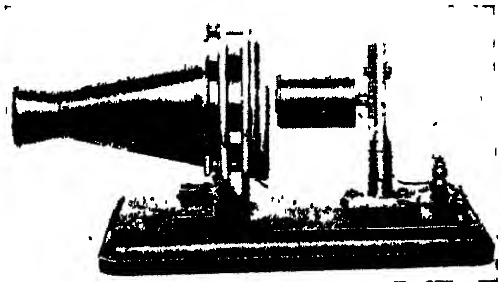
Bell's speaking telephone due to accidental discovery during telegraph experiments

During these trials he suggested to several friends the possibility of transmitting speech electrically, and it is evident that he was familiar with the attempts made by Reis in that connection He was advised to persevere in the development of his harmonic telegraph, however, and the speaking telephone invented by Bell owes its existence in part to an accidental discovery made during these telegraph experiments. His mechanician, Thomas A. Watson, states that he was engaged on June 2, 1875, in vibrating one of the springs at the sending end of a short line in an attic on Court Street in Boston while Professor Bell was tuning a spring in another room at the other end of the line. The vibrating contact at the sending end accidently became welded together by the heat of the spark, and Watson in trying to break the fused, contact plucked the spring several times. Professor Bell rushed in from the next room and cried, "What did you do then?" Bell had heard the exact sound of the sending spring reproduced by the spring at the receiving end of the line. It took him but a moment to realize that the vibrations of a spring placed near an electromagnet connected in a closed circuit will cause the current in the circuit to vary in strength at the same frequency as the vibrations of the spring. Since Professor Bell, like his father before him, was an expert in the science of sound and had devoted many years to the problem of teaching the deaf and dumb to speak, he quickly saw the possibility of replacing the spring by a diaphragm large enough to vibrate in accordance with the varying air pressure produced by the voice. After much experimentation with various shapes of diaphragm, a transmitter and a receiver were made which transmitted speech fairly well.

The patent for this invention was issued on March 7, 1876, and proved to be the most valuable single patent ever issued in any country The instrument was demonstrated at the Centennial Exposition in Philadelphia in 1876 and created a sensation among those who were able to appreciate its importance Lord Kelvin who, with Don Pedro of Brazil, was among those to hear its uncanny repetition of spoken words, pronounced it "the most wonderful thing in America" In 1921 there were nearly 13,000,000 telephones connected to the lines of the American Telephone and Telegraph Company, and half a million more without regard to ownership — say one to about every eight persons. Its circuits contain 25,000,000 miles of wire and its employees number over 231,000. The average number of daily messages transmitted through the system exceeds 33,000,000.

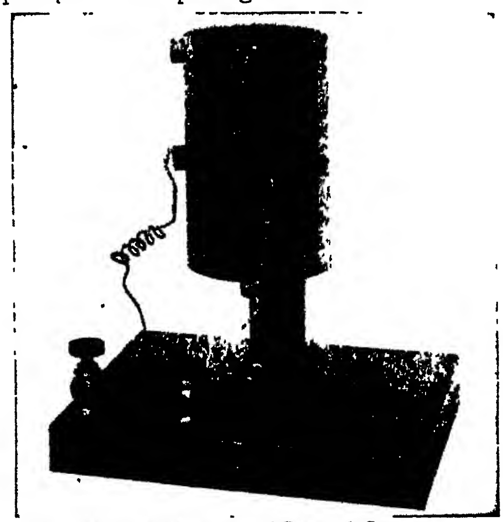
The receiver that we take from the hook of the present-day telephone is substantially the same as that used in Bell's original instrument. The principal difference lies in the use of a permanent magnet in place of the former soft iron core, a change which Bell introduced in 1877. At the same time a group of investigators at Brown University made several improvements in the construction of the telephone, resulting in a simpler and more compact form. With this improved instrument Professor Bell inaugurated a series of lectures in various cities in which he described and demonstrated his telephone before large audiences.

The Bell Telephone Company, then an association of owners of the Bell patents, was organized and began to lease telephones for private use at ten dollars per year. In 1878 the American Speaking Telephone Company, a subsidiary of the Western Union Telegraph Company, was formed and proceeded to manufacture telephones of the Bell type in open competition with the original company. An important improvement in the telephone was made almost simultaneously by Emile Berliner and Thomas A. Edison, who independently suggested the substitution of a microphone transmitter for Bell's electromagnetic transmitter The Berliner microphone contained a small metal knob which was held lightly in contact with a plate attached to the center of the sending diaphragm, while the Edison microphone contained a similar contact of carbon on a metal plate In both instru-



Courtesy American Telephone and Telegraph Co
PROF BELL'S ORIGINAL CENTENNIAL MAGNETIC TRANSMITTER

ments the varying pressure of the sound waves on the diaphragm produces a corresponding variation of the contact resistance in the microphone and thus causes the current in the line to vary in strength at the same frequency as the sound waves. Reis would have obtained a similar result if he had prevented his vibrating diaphragm from opening the circuit.



Courtesy American Telephone and Telegraph Co
PROF. BELL'S ORIGINAL CENTENNIAL RECEIVER

The Western Union Telegraph Company purchased the Edison microphone patent and, since it controlled most of the telegraph lines in the country, became a serious competitor of the Bell Company.

Marvelous growth of the Bell Company, and the good fortune of its shareholders

In 1878 Theodore N Vail, formerly in charge of the Railway Mail Service, became general manager of the Bell Telephone Company, and the subsequent commercial development of the telephone was due in a considerable measure to his leadership The Bell Company adopted an improved microphone transmitter invented by Francis Blake, Jr, and brought suit against the Western Union Telegraph Company for infringement of the original Bell patent In 1879 the Western Union was required to withdraw from the telephone business, and the stock of the Bell Company, which had been offered previously at $50 per share with few buyers, rose in value to $1000 per share. In 1879 the name of the company was changed to the National Bell Telephone Company, and in 1880 the name was again changed to the American Bell Telephone Company, under which it operated for the next five years.

© Pine Macdonald

THEODORE N VAIL

The late president of the American Telephone and Telegraph Co to whose leadership was principally due the commercial development of Prof Bell's invention

With each reorganization came new issues of stock which multiplied the value of the original shares many times It has been computed that an original investment of $50 in the Bell Telephone Company has returned to the present time over $100,000

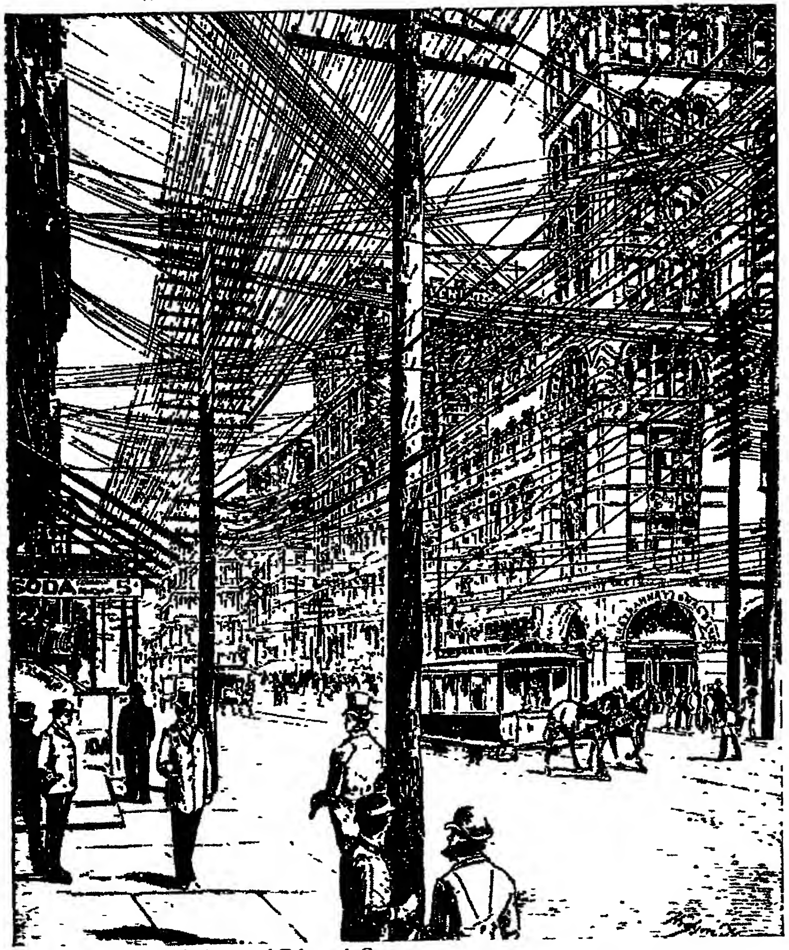
The huge success of the Bell telephone was not attained however, without continuous technical as well as commercial obstacles In its early years a single diaphragm serving both as transmitter and receiver was employed, so that one must alternately speak and listen to the same diaphragm The subscriber obviously became confused in this operation and a sign was attached to some of the telephones which read, "Don't talk with your ear and listen with your mouth."

City wires are buried and infringers of basic patents strictly held to account

Following the invention of hand-drawn copper wire by Thomas B. Doolittle, a telephone line was constructed between Boston and New York and was placed in operation in 1884. The company was reorganized in 1885 and was given the present name, American Telephone and Telegraph Company. At this time the congestion of overhead wires in New York City became so great that it was found necessary to lay the wires underground in conduits. While surmounting these difficulties the telephone company was compelled to bring suit against various persons for infringement of its basic patents. From its beginning until 1896 the company pressed and won over 600 lawsuits, five of which reached the Supreme Court.

The microphone transmitter was greatly improved about 1890 by A. C. White. The White microphone contains a small box filled with hard grains of carbon. The sound waves beating upon the transmitter diaphragm cause these particles to pack more or less closely together. The contact resistance of the mass of carbon granules is thus made to vary widely in accordance with the sound waves produced by the voice. This type of microphone is used in the transmitter of all modern telephones.

SOLVING THE OVERHEAD WIRES PROBLEM IN A GREAT CITY



Courtesy American Telephone and Telegraph Co

BROADWAY AND JOHN STREET, NEW YORK, IN 1890 AND TODAY

The density and confusion of overhead wires in 1890

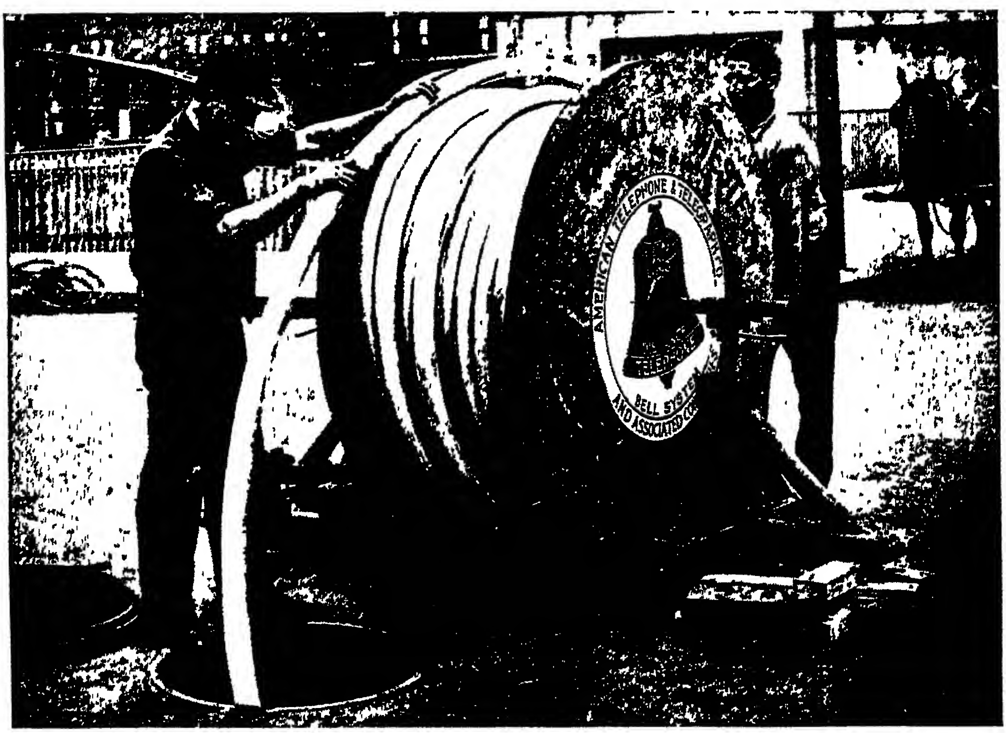
The same corner as it is today, all wires underground.

The telephone exchange

The idea of establishing a telephone exchange by which one telephone may be connected with any other telephone appears to have been suggested by Edwin T. Holmes, who conducted such an exchange in 1877 in connection with his burglar alarm system in Boston. Speech transmission at first was so poor that a subscriber must tell the operator at the exchange what message was to be repeated to another subscriber. At present the pair of wires that leaves our telephone set is carried overhead on poles or underground in lead-covered cables to a building where hundreds of similar wires are brought together for interconnection.

In the modern exchange many operators are seated side by side before a telephone switchboard Each of the operators is equipped with a receiver and a transmitter, which are held in position by straps, leaving both hands free. The front face of the board is perforated with a large number of small holes called "jacks" and beside each hole is located a tiny electric lamp Each of these holes represents the terminal of a telephone line Between the operator and the vertical face of the board is a narrow bench from which hundreds of brass-tipped terminals protrude. These are called "plugs" and are attached to the ends of flexible cords of suitable length.

When a subscriber lifts his receiver from the hook, one of the tiny lamps flashes up on the board and the nearest operator picks up one of the plugs and inserts it in the jack adjacent to the lighted lamp The lamp goes out, but another lamp on the bench beside the cord is at once lighted. The operator then presses a key on the bench which connects her telephone set with the subscriber's and says, "Operator" Upon receiving the number desired, the operator picks up another plug, connected under the bench to the first, inserts it in the jack which bears the desired number, and presses a key which rings the telephone bell of the person called

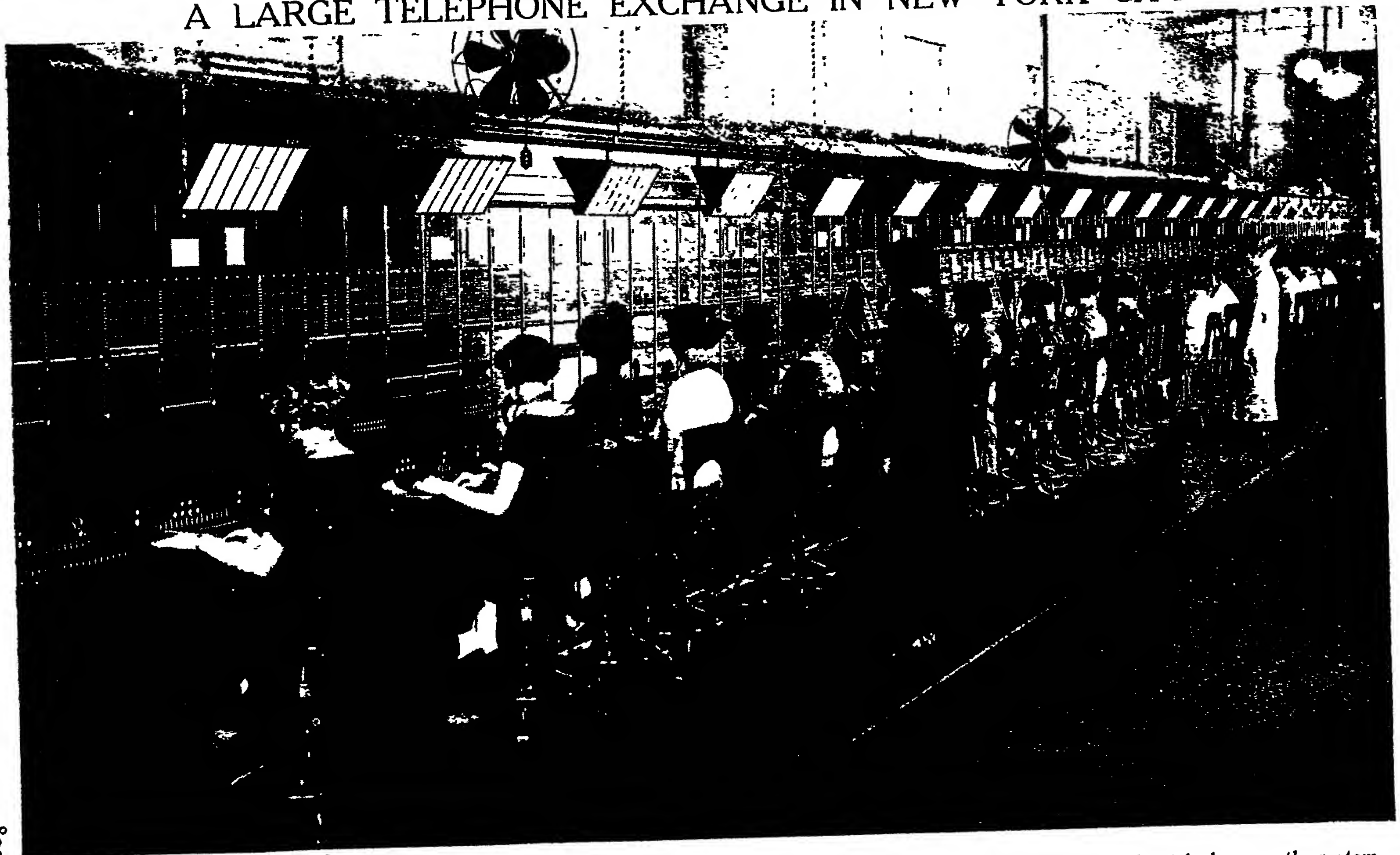


Courtesy New England Telephone and Telegraph Co.

LAYING A LARGE TELEPHONE CABLE

Through this single cable 1200 persons can talk with 1200 others without confusion or interference.

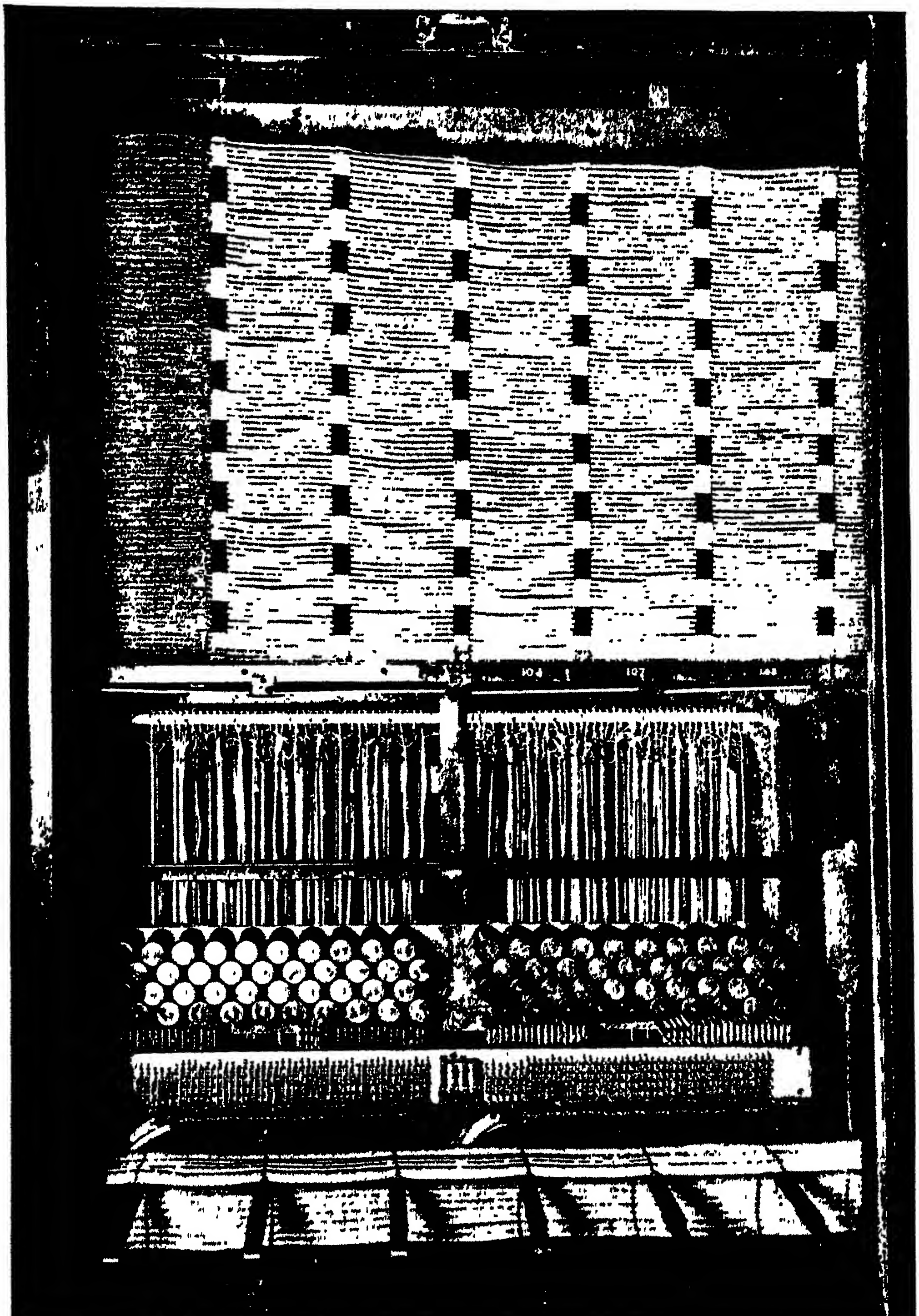
A LARGE TELEPHONE EXCHANGE IN NEW YORK CITY



Courtesy American Telephone and Telegraph Co

One of these girls says "Number, please," when you take your receiver from the hook, and connects your telephone with any other telephone on the system.

HOW THE BOARD LOOKS FROM BEHIND

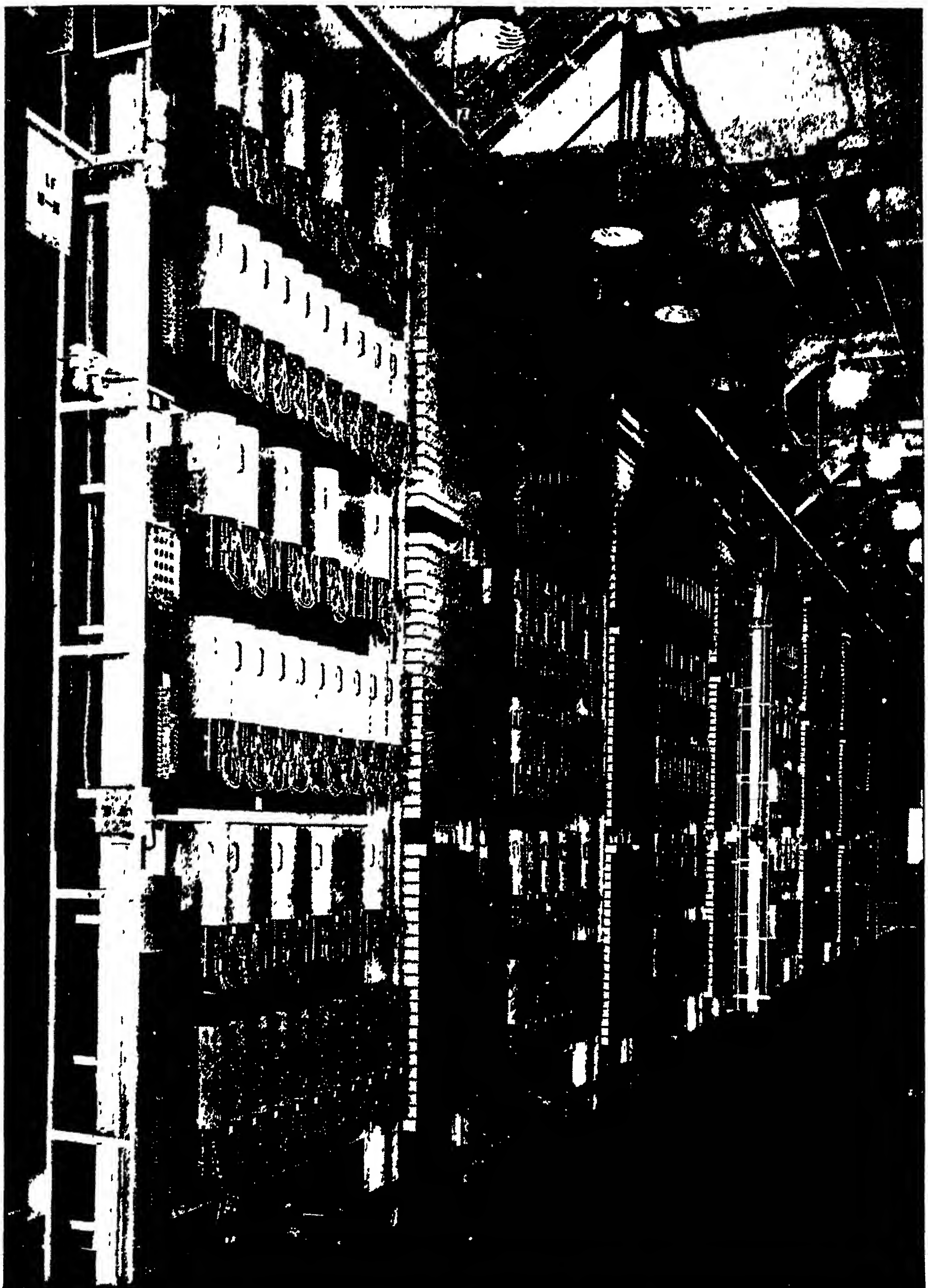


Courtesy American Telephone and Telegraph Co

BACK OF A TELEPHONE SWITCHBOARD

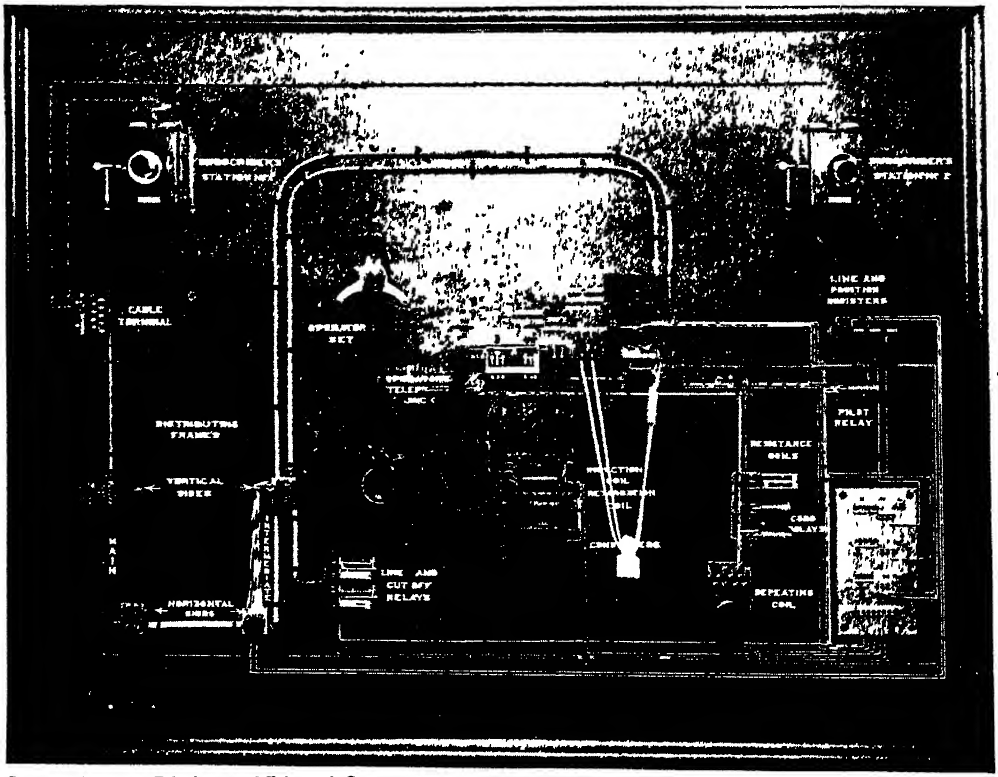
The terminals of the various telephone lines are brought together at this point so that all lines may be within reach of the operator who sits on the other side of the board.

A STEP-BY-STEP DIAL SWITCHROOM



Courtesy American Telephone and Telegraph Co.

The machine that replaces human ears and hands The subscriber indicates on a dial on his telephone the telephone number he requires Electric currents then travel from the dial to the exchange, and there set in motion a mechanism which performs all the work of connecting the two lines.



Courtesy American Telephone and Telegraph Co

A TELEPHONE DISPLAY BOARD

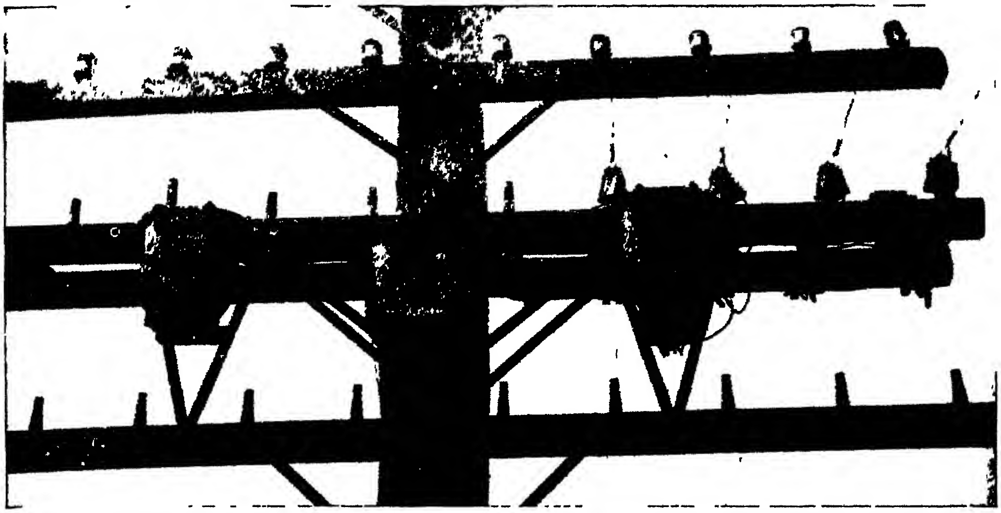
On which are shown the various circuits and devices by means of which a telephone operator connects one subscriber with another in the same exchange

As soon as the person answering the call lifts the receiver from the hook, the lamp adjacent to the first cord is extinguished, indicating to the operator that the desired connection has been made. Since the operator's telephone is disconnected from the line after receiving the number desired, she is free to make other connections. When the subscriber on any line replaces the receiver on the hook, the lamp adjacent to the corresponding cord flashes up, the operator withdraws the plug, extinguishing the lamp, and returns the plug to the bench. In a busy telephone exchange the switchboard lamps are constantly flashing on and off and are accompanied by the calls of "Operator" and the sound of the clicking plugs. To the visitor the front of the board seems quite simple, but the back of the board is most complicated in its construction. The back of a telephone switchboard is shown on page 810.

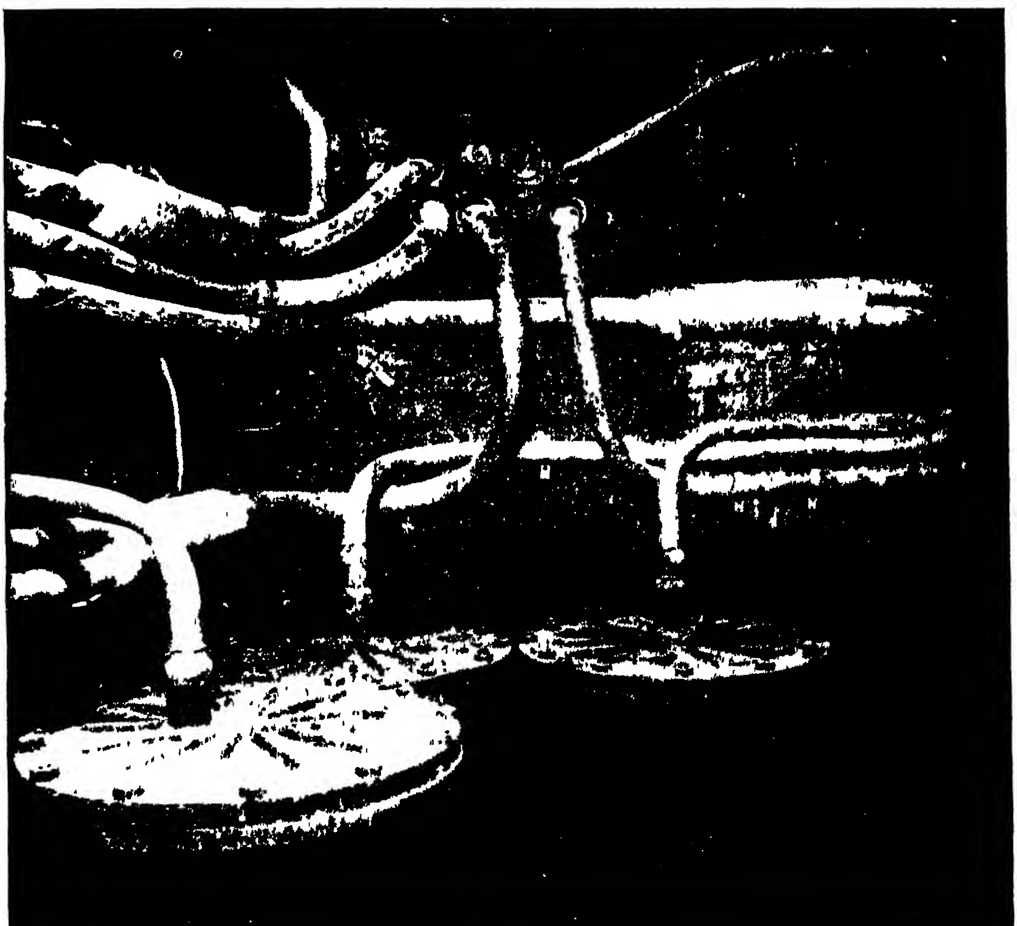
In another type of exchange which is increasing in use the connections are made by an automatic machine which is controlled by the person making the call. Instead of waiting for the operator to ask for the number desired the subscriber on an automatic system connects his telephone set with that of any other subscriber by turning a numbered dial on the base of his telephone to the successive digits of the telephone number desired. The automatic machine — a typical form is shown on page 811 — connects the two telephones and the calling subscriber may then ring the bell on the telephone of the other subscriber.

Improving the long-distance lines

For many years after the invention of the telephone, speech transmission over lines more than a few hundred miles in length proved impossible and in shorter lines it was frequently difficult to transmit



LOADING COILS ON AN OPEN-WIRE LINE



Courtesy American Telephone and Telegraph Co

UNDERGROUND MAN-HOLE CONTAINING LOADING COILS

In both cases the coils make it possible to send clearer messages over long distances.

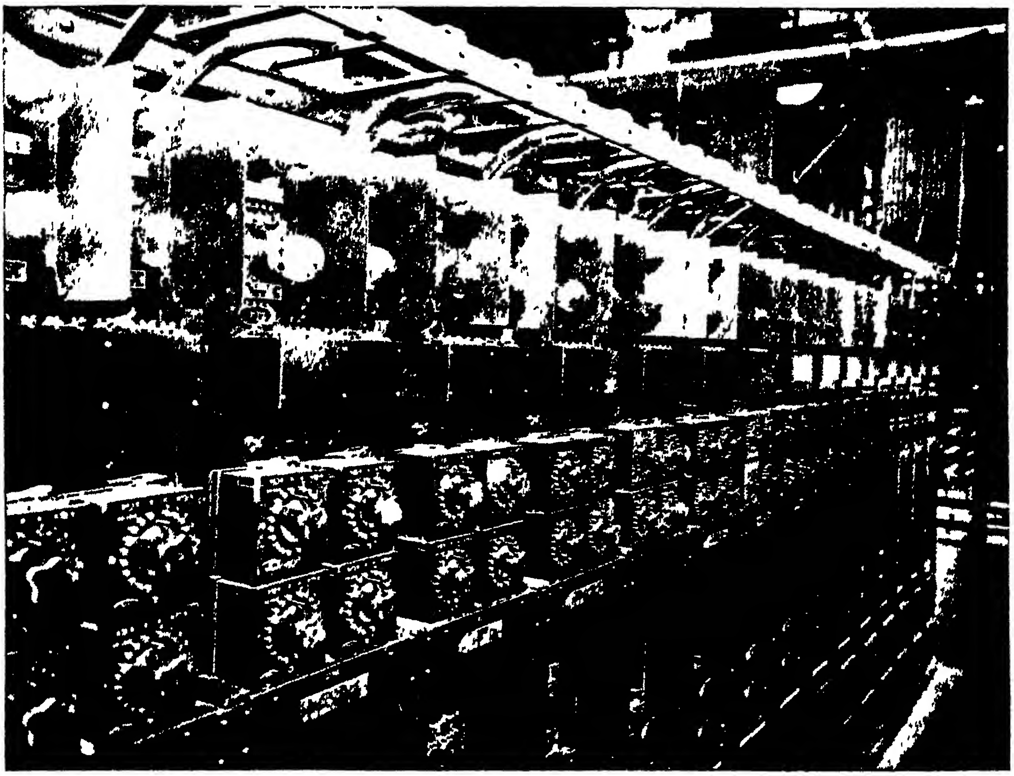
speech clearly. The change in quality of speech transmitted over long lines is due to the fact that the various sound frequencies of the human voice, which we recognize in sequence as words, are not transmitted with equal strength over the line; some are partially absorbed in transmission while others may be increased in relative loudness. This distorting effect is further increased by the fact that the respective frequencies do not arrive at the distant receiver in precisely the same order that they issue from the mouth of the speaker since some of the frequencies are retarded slightly with respect to others. Under such conditions it must be evident that while such distortions may not be of great magnitude the result at the receiving end of the line is confusing.

A professor at Columbia University, Dr. Michael I. Pupin, recognized that this distortion was due to the unequal transmission of the various frequencies of the voice and made a mathematical investigation of the existing conditions for the purpose of seeking a remedy. The study of mathematics to many persons is less attractive than that of many other subjects because it appears to lead toward less practical results. The fallacy of this view is apparent in this instance, as in many others, for Dr. Pupin's mathematical investigation revealed to him the remedy for the imperfect transmission in long lines. He advised the telephone companies to insert coils of wire at definite places in their lines and predicted an improvement in speech transmission The lines between New York and Chicago were thus equipped with "loading coils," and with marked success. Coils were later installed in the lines west of Chicago as far as Denver so that one could talk between New York and Denver, a distance of 2200 miles. Coils of similar character have been installed in the underground telephone cables which connect Boston, New York, Philadelphia and Washington. London and Paris have been connected by a "loaded" telephone cable laid across the English Channel, and land lines originating at Paris will eventually connect London with Berlin, Vienna and Rome.

Although Dr. Pupin's invention made it possible to extend the distance over which the voice could be transmitted, transcontinental communications would undoubtedly have proved impossible without the added installation of "repeaters" which would work in conjunction with the loading coils The telegraph companies have used repeaters for many years, but the type employed by them is too sluggish in action to reproduce the human voice. After many contrivances had been tried and found defective, a satisfactory repeater was finally evolved which embodies the principle of the electron tube Since this device is described in detail in the chapter on radio communication, it will suffice to explain here that an electron tube consists of a highly evacuated glass bulb containing an incandescent filament, a grid of wires, and a thin plate placed side by side in the order mentioned If the two ends of a telephone line are connected respectively to the grid and the filament, the telephone current sent over an extension to this line connected to the plate and the filament will be many times greater than in the first line and will vary in strength in exact duplication of the original weak one.

The installation of these repeaters at various points between New York and San Francisco has made it possible to talk clearly between these two cities. With the completion of the submarine telephone cable between Key West and Cuba, telephone communication is now established between Cuba and Catalina Island. The voice in this instance is carried under the ocean from Cuba to the United States, across the continent to California, and then makes the final leap by radio telephony to Catalina, a total distance of 5470 miles.

The steadily increasing traffic over our long-distance telephone lines has made it desirable that some method of multiplex telephony be devised which would enable several telephone messages to be transmitted over one pair of wires. The first step in this direction was made about 1910 with the introduction of the so-called "phantom" circuit, by means of which three telephone messages may be transmitted simultaneously over two pairs of wire.



Courtesy American Telephone and Telegraph Co

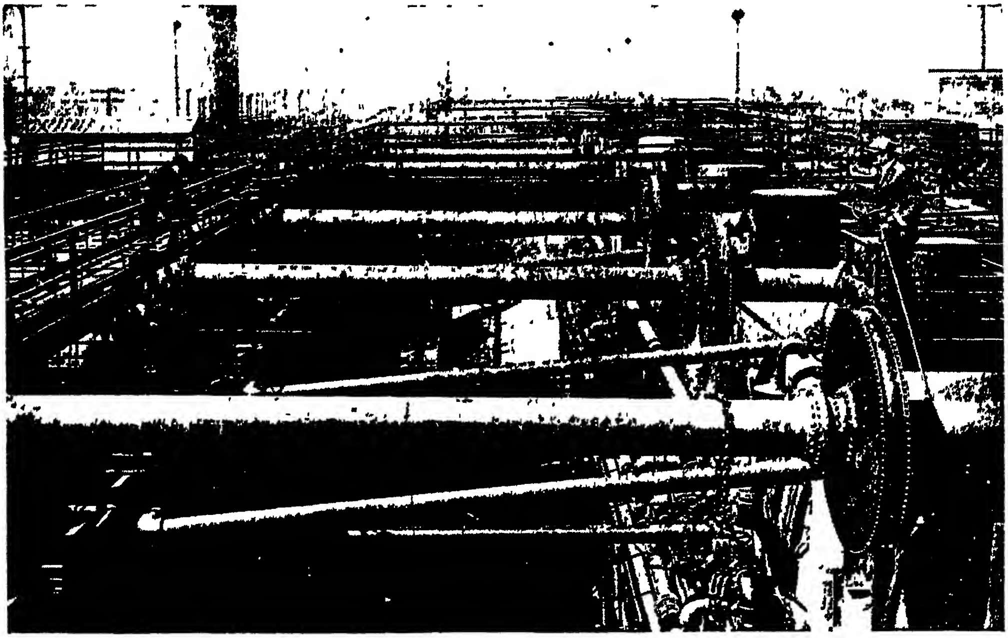
THE TELEPHONE REPEATER INSTALLATION AT THE PRINCETON REPEATER STATION

The electron tubes shown at the top of the board amplify the feeble telephonic currents and send them on with increased strength.

More recently a method called "carrier" telephony has been developed, which enables several telephone messages to be sent over one pair of wires in any direction at the same time In the carrier system each person in speaking into the transmitter varies the strength of a very high frequency alternating current maintained continuously in the line. This alternating current is produced by an oscillating electron tube which resembles the telephone repeater in construction. The person speaking into the transmitter is said to "modulate" this high frequency current, which serves as a carrier of the voice frequency but reverses so rapidly that it produces no sound in the telephone receiver. The voice frequency does reproduce itself in the diaphragm of the receiving instrument, however, and speech transmission is as clear as in the ordinary telephone line.

The most important element in the multiplex carrier system is a device at the receiving end called a "filter." Filters are connected at each end of the line between each pair of telephones. Their function is to allow but one definite carrier current to pass through, so that with several carrier currents of different frequencies in the telephone line at the same time each filter at the receiving end will allow only one of the carrier currents to pass through to its receiving set. In this way the various telephone conversations conducted over one pair of wires at the same time are sorted at the receiving end and delivered to the proper subscribers. The carrier systems in service permit five telephone conversations to be carried on over one pair of wires, and it is probable that this number may be increased considerably.

The same system has also been applied to multiplex telegraphy so that twenty telegraph messages may be sent over one pair of wires at the same time.



LOOKING DOWN ON THE STILLS FROM ABOVE THE VAPOR PIPE LINES

© Ewing Galloway, N Y

THE ALARMING INROADS ON THE NATION'S RESERVE OF OIL

A long train of tank cars laden with oil from the East Chicago, Indiana, refinery of the Sinclair Consolidated Oil Corporation ready to be shipped away to the consuming public. This refinery is at the eastern end of a pipe line from the Oklahoma and Kansas fields.

OUR WEALTH IN MINERALS

Supremacy of the United States and the
Rapid Development of Its Sources of Supply

NEED OF PUBLIC REGULATION OF CONSUMPTION

PIERRE LEROY-BEAULIEU, a noted French economist, has remarked that the United States owes its industrial greatness more largely to its minerals than to any other single factor. And well justified appears this belief when we consider the striking supremacy of this country in this particular field of natural resources. Not only is the United States the leader in coal and iron, but it also surpasses in the production of petroleum, natural gas, silver, sulphur, molybdenum, arsenic, salt, and lime phosphates; it manufactures the largest share of the world's aluminum, and in gold it is rivaled only by Australia and South Africa The United States produces more than one-half the world's copper, holds primacy in lead, and in zinc has wrested the lead from Germany No other country can hope to rival the United States in its mineral wealth.

Minerals comprise an exceedingly large part of the nation's annual production At the present time the value of our annual product of the mines is over five billions of dollars. In only one industry, agriculture, is this mark exceeded.

Mineral resources are not to any appreciable extent the result of existing natural forces; they were manufactured by the work of agents operating millions of years ago. Before the earth's crust had hardened, rocks were hurled by volcanic action from the interior and spread over the surface. Thrusting aside the solid rocks, the igneous rocks became a part of the earth's crust, the deposits ready for man's exploitation millions of years later. Volcanic action also caused vapors, bearing minerals in solution, to issue forth.

DISTRIBUTION AMONG THE CONTINENTS OF THE WORLD'S MINERAL OUTPUT 1928

Commodities	World Output in Metric Tons	Per Cent Contributed					
		Europe	North America	South America	Asia	Africa	Oceanica
Antimony	28,610	11 4	12 6	10	66	*	*
Bauxite	1,994,000	58 8	19 2	18 4	–	–	–
Chromite[1]	449,000	13 3	7 6	*	12 9	52 6	12 8
Coal	1,450,000,000	52 6	40	*	4 1	*	1 1
Copper	1,716,067	7	62	20	3	7	*
Gold[2]	19,756,000	6	25	2	7	58	2
Graphite[3]	151,100	55 5	12 3	–	21 7	10 2	–
Iron ore	154,189,000	55 5	43 4	*	*	*	*
Lead	1,705,000	25 1	58 8	1 3	4 6	1	9 2
Magnesite	698,474	74	20 1	–	3 6	*	1 4
Manganese ore	2,868,700	30	1 7	13 3	37	18	*
Mica	20,801	*	55	*	23 8	21	*
Molybdenum[4]	3,716	*	99	–	–	–	*
Nickel ore	1,574,958	–	92	–	–	–	7 6
Petroleum[5]	1,324,734	10	71	12	7	*	–
Phosphate	9,907,385	*	10	–	*	50	8.1
Silver[6]	257,273,000	4	76 1	10 1	5 6	*	4
Sulphur	2,560,000	14 3	83 3	*	2	–	–
Tin[7]	178,164	2 3	–	23 2	66 6	6 4	1 5
Tungsten	12,000	7	8 3	*	83 8	–	*
Fluorspar	1,419,707	52	45 5	–	*	2 2	*
Barium	363,963	27	71 4	–	*	*	1 2
Zinc	1,419,707	48	47 6	–	*	*	3 8
Platinum[6]	198,000	53	6	36	*	16	*

[1] Partly estimated. [2] Fine ounces [3] 1927 latest figures. [4] 1000 pounds content [5] 1000 barrels [6] Troy ounces. [7] Long tons. *Less than 1%.

In the Carboniferous Age vegetation was abundant. Trees grew and fell. This tree fiber is the source of our present coal.

But all this is the result of the past work of natural forces. Mineral wealth is a mere accident of creation; what nature has granted or denied cannot be appreciably changed by man. All man can do is to utilize intelligently and thoughtfully these gifts of nature.

The annual output of the mines and quarries of the United States

The following table, the figures of which are derived from the census returns on mines and quarries, indicates the extent and variety of the United States annual production of mineral wealth. The figures are for the year 1929. The value of our mineral products before the Great War amounted to less than one billion dollars. The astounding growth in value is due partly to increase in production, and partly by reason of the rise in prices. Now, as we have said, the annual product, or contribution to the nation's wealth, exceeds five billions of dollars

A YEAR'S MINERAL WEALTH

The Output of the Mines and Quarries of the United States

Mineral Products	Value of Products
Coal	$1,383,675,000
Petroleum and natural gas	1,818,400,000
Iron	929,007,000
Copper	352,504,000
Precious metals	81,460,000
Zinc and lead	165,415,000
Cement	255,105,000
Stone	199,922,000
Sand	108,700,000
Aluminum	51,864,000
Lime	33,387,000
Gypsum	31,293,000
Sulphur	43,800,000
Salt	27,335,000
Barite	19,709,000
Other minerals	328,424,000
Total value of all mineral products	$5,830,000,000

To consider all of these minerals separately is impossible. Brief mention, however, can be made of the more important. First of all, let us consider the mineral fuels.

Only in comparatively recent times has man resorted to the use of minerals for fuel. As late as the middle of the nineteenth century forests were the chief source of fuel in all countries, save possibly England and one or two other European countries. Today, however, wood occupies a comparatively subordinate position as a fuel.

The principal mineral fuels are coal, peat, petroleum, and natural gas. In coal the superiority of the United States has already been indicated in an earlier chapter This country also possesses large amounts of peat It has been estimated that in the glacial regions of northeastern United States, and in several states of the South, there is deposited nearly thirteen billions of tons. This exceeds the total amount of the coal yet mined. In Europe something like ten million tons of peat are annually used. But in the United States the comparative cheapness of coal has retarded the utilization of peat. As the price of coal rises, however, the extraction of peat should become commercially profitable. As a heat producer it is less efficient than coal, and its total amount is less than one two-hundredth that of coal Its future, said the late President Charles R Van Hise of the University of Wisconsin, will be confined to use as home-fuel, as a source of the fertilizer, ammonium sulphate, in the production of gas, and in the manufacture of charcoal.

In petroleum the primacy of the United States is firmly established. This is well indicated by the following table, compiled by German authorities. Recent figures are really less significant than the old, by reason of the disturbances occasioned by the Great War. Russia, for example, is certain eventually to regain its importance as a producer.

PRODUCTION OF THE WORLD'S PETROLEUM WELLS IN A PRE-WAR YEAR

(In metric tons of 2205 pounds)

Country	Production	Per Cent of World's Total
United States	29,108,000	62 2
Russia	9,318,000	19 9
Mexico	2,208,000	4.7
Roumania	1,807,000	3 9
Dutch East Indies	1,478,000	3 2
Galicia	1,187,000	2 5
British India	990,000	2 1
Peru	233,000	0 5
Japan	223,000	0 5
Germany	135,000	0 3
Other countries	78 000	0 2
The World	46,765,000	100 0

Even before the war the United States produced three-fifths of the world's supply, and thrice surpassed its nearest rival

The name "petroleum" means rock-oil It is a natural oily substance obtained by boring through the earth until the reservoir is reached. Many and useful are its products At the one extreme we have heavy artificial asphalt, such as is used in the paving of streets. At the other end are the light ethers, which find such a merciful use as anesthetics in surgery. In between these two extremes are an enormous variety of useful and well-nigh indispensable products. The fuel oils, largely by-products of the refining of petroleum, are used not only in heating, in producing power for manufacturing plants, but also for supplying railroad locomotives and ocean steamships. In this last use they have already effected what amounts to a virtual revolution in the construction and operation of ships. Gasoline has made the automobile possible, and the enormous development of the automobile industry is already putting a severe strain upon the world's petroleum output. Then there are naphthas, used in various commercial processes. Kerosene, not long ago the almost universal illuminant, remains indispensable for light in small villages and farms. It has an annually increasing use as a fuel for farm tractors, and it is not unlikely that in the future it may be used as fuel for automobiles as well. The lubricating oils and greases derived from petroleum are for some purposes very much better than the animal and vegetable oils which they have superseded. The paraffin waxes got from petroleum have a variety of important uses, including a new function in surgical dressings for burns. Petroleum coke, purer than that obtained from coal, is used in metallurgy and in the manufacture of carbons. Despite the discovery from time to time of new petroleum fields in different parts of the world, the price of most petroleum products has steadily advanced. Its use for power is, therefore, likely to decrease. Alcohol may well take its place, and in its manufacture there is no depletion of mineral resources.

In the Diesel type of engine a large variety of vegetable and animal oils, as well as mineral oils, can be used for fuel. This engine depends, however, upon the injection of small particles of fuel into air which is already in a state of very high compression Because of technical difficulties arising from this peculiarity, it has not yet been successfully adapted to use in automobile engines. Research in this and in similar fields is proceeding with promising results In the long run petroleum will have to be saved for those uses in which it is almost indispensable.

Natural gas is the most perfect fuel yet discovered by man This can be readily comprehended when we consider that coal produces its maximum power when it is first transformed into producer gas But gas, manufactured in this way, contains a great deal of inert nitrogen, of which natural gas is free. For illuminating purposes, natural gas is the cheapest of all forms of artificial light. And where coal is dear it often is used as fuel.

The existence of natural gas has been known for centuries. The ancient Persian Fire Worshipers made regular pilgrimages to the shores of the Caspian Sea, where they could discern columns of flame issuing from the earth. It remained for the United States to find a more practical use for it.

This country possesses more extensive natural gas fields than any other country. Unfortunately, some authorities estimate that if the present increase in consumption continues the existing supply cannot last more than twenty-five years.

Of the minerals valuable primarily as raw materials rather than as sources of energy, iron is, of course, the most important It is not too much to say that it is iron which gives coal much of its economic value. Wherever both coal and iron can be brought cheaply together, there the chimneys of factories are to be seen; there the population will be dense. In another chapter the supremacy of the United States in respect to iron and steel is noted, and how easy access to both coal and iron has brought about a concentration of a large part of her manufacturing industries in the eastern and northern sections,

CONTRIBUTION OF UNITED STATES TO WORLD'S OUTPUT OF MORE IMPORTANT MINERAL COMMODITIES

Commodity	Per Cent Produced by the United States	Leading Producing Country
Coal	39	United States
Iron ore	45	United States
Copper	51	United States
Lead	42	United States
Zinc	45	United States
Gold	14 28	Transvaal
Silver	30 56	United States
Platinum	2 5	Russia
Tungsten	12	United States
Nickel	[1]	Canada
Petroleum	71	United States
Natural gas	95	United States
Antimony	[1]	France
Mica	47	United States
Pyrite	3	Spain
Sulphur	70	United States
Phosphate	38	United States
Potash	I	Germany
Nitrates	[2]	Germany
Bauxite	30	France
Graphite	4	Japan
Magnesite	[3]	United States
Tin	[1]	United Kingdom
Salt	28 5	United States
Mercury	7	Italy
Chromite	[1]	Japan
Manganese	I	United States
Asbestos	[1]	Italy

[1] Less than one per cent
[2] No production recorded
[3] Total world production not recorded

Stone, copper and iron have successively formed the material basis of civilization, and the ages in which each of these was dominant have become known as the Stone, Bronze and Iron Age. Today stone serves many uses other than house and road building. Its quarrying is one of the large industries. Even before the war the annual limestone product amounted to forty-seven millions of dollars, and granite and traprock to twenty-four millions more. Limestone is quarried in many parts of the United States, and its various products are used for many purposes — in the making of lime and cement, as a structural material and as a flux for smelting iron and copper ore. Marble, confined more largely to a few states, is much used for monuments, interior decoration and building material.

The New England States produce much of the granite used for buildings and bridge construction work. None of the "stones" are, however, of sufficient industrial importance to affect considerably the localization of the country's industries. Slate, used principally for roofing purposes, is the only American stone, aside from phosphate rock, which is exported to any considerable extent. Bulkiness in relation to value and a comparatively even distribution of the world's supplies will prevent American stone from becoming an important commodity in foreign trade.

Where neither timber nor stone was readily accessible, civilized man was subject to a serious difficulty until he discovered how to make brick. As our forest resources dwindle, brick is bound to come into wider use.

All in all, our clay products are among the largest of our mineral industries. In 1929 the value of brick and tile, terra-cotta and fire-clay products was $296,488,702. Pottery products amounted to $108,757,233. Nevertheless, the country is still an importer rather than an exporter.

The increasing prominence of the cement industry is notable. From 1900 to 1929 the output multiplied ten times. The growing importance of Portland cement is the largest factor in this increase Portland cement is made of clay and limestone, heated to about 3000 degrees Fahrenheit. It has the invaluable quality of hardening under water. Without cement it would be difficult for much of our railway-tunnel and subway construction to be accomplished. Steel and cement are indeed the foundations of modern engineering.

Turning from the structural minerals to the metals, we are first of all impressed with the magnitude of the country's copper resources. Since the last decade of the nineteenth century the United States has produced more than half of the world's copper supply. All European countries are obliged to import copper from us; Germany, France and Great Britain have been particularly large buyers of our copper ingots and plates for manufacturing. At times Europe requires nearly half of our total output.

In recent years the use of copper has increased more rapidly than that of iron Fifty years ago the world produced only one ton of copper to every one hundred tons of iron, now the ratio is more nearly one ton of copper to fifty tons of iron With the increasing employment of electricity, the world has turned again to copper, as it did in the earliest historical times. Next to silver, copper is the best conductor of heat and electricity In fact, it might even be said that we have passed into what might be called a new "Copper Age"

GROWTH OF THE WORLD'S COPPER OUTPUT

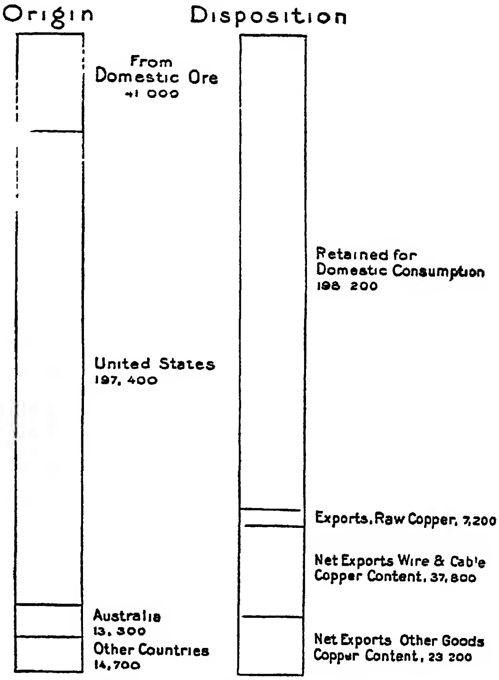
(In short tons of 2000 pounds)

(From figures compiled by the Bureau of Mines, Department of Commerce)

Country	1913	1920	1929
United States	612,242	604,531	1,026,348
Canada	38,488	40,801	121,151
Mexico	57,973	54,225	86,759
Chile	46,587	109,076	348,365
Peru	30,618	36,356	59,980
Germany	29,362	16,508	31,967
Japan	73,305	74,728	83,189
Belgian Congo	8,165	20,902	149,622
Cuba	[1]3,747	[1]9,259	15,740
Yugoslavia	——	2,685	22,790
Unspecified	190,140	88,098	181,193
The World	1,090,627	1,057,163	2,127,104

[1] Estimated [2] Preliminary

Copper differs from both coal and iron in one important respect. It is relatively high in value in proportion to its bulk. For this reason it is profitable to transport it to industrial centers rather than to create industrial centers at the points where copper is mined. The distribution of the world's copper, unlike the distribution of the world's coal and iron, does not control the distribution of the world's population. Nevertheless, our copper remains one of our greatest national assets. The experience of the Great War proved, if proof were necessary, that the possession of great supplies of copper is a fundamental prerequisite to military strength and to national independence. Take, for example, the position of Germany in the year just preceding the war.



GERMANY: SUPPLIES OF COPPER, 1913
(In metric tons)

The above chart shows just where the copper used in Germany came from before the war. It will be noted that the amount received from the United States just about sufficed to cover Germany's domestic consumption, and that her exports in raw or manufactured form were no greater than the amount she secured from domestic sources and from other countries than the United States.

Whether by design or not, on the eve of the war, Germany was unusually well stocked with copper. Nevertheless, because she was using for munitions alone at least 50 per cent more than she used annually for all purposes before the war, her accumulated stocks availed little. With her principal source of supply shut off, she had to turn to the copper that had already been devoted to other uses. Copper roofing, bronze bells, copper telephone, telegraph, and other electrical transmission wires were all put into the melting-pot. Even bronze bearings from machinery, copper and brass household utensils, many of them family heirlooms, and bronze statues were transformed into munitions.

In this way, it is said, Germany secured over a million tons of copper But, at that, her supply at the end of the war was just at the verge of exhaustion There are many experts who believe that for the lack of copper alone it would have been impossible for Germany to have carried the war through another year.

The principal copper-producing states are Michigan, Montana, Arizona, and Utah. In the Kewenaw peninsula copper is found pure, and it was from this source for a long time that practically all of the country's supply was obtained. Now most of the copper is found in the ores Formerly the expense of reducing the copper ores was prohibitive. Recent improvements in metallurgy have, however, made possible the economic utilization of the ores, and the western states of Montana, Arizona, and Utah have accordingly become more important as copper producers.

Where the world's lead comes from

Lead smelting is one of the country's oldest industries. So far back as 1825 as much as 1500 tons of lead were produced annually. By 1880 production had reached 100,000 tons a year, while by 1913 the output had reached 485,000 tons.

WHERE THE WORLD'S LEAD COMES FROM AND WHERE IT IS USED

(In metric tons of 2,204.6 pounds)

(From figures compiled by the *American Bureau of Metal Statistics*)

Country	Production	Consumption
United States	538,087	523,500
Mexico	252,141	———
Australia	166,693	*12,000
Spain	122,308	33,400
Germany	110,800	165,300
Belgium	60,920	40,000
France	20,104	155,800
Great Britain	10,383	288,400
Not specified	383,029	338,500
Total	1,664,465	1,556,900

*Estimated

Today the United States holds the primacy in lead, producing about one-third of the lead output of the entire world. This primacy, however, is by no means so decisive as in the case of copper.

Copper, unlike lead, a permanent asset

Lead, zinc and silver are generally joint products of the same ore deposits. Until within very recent years the relatively low prices of silver and of zinc have discouraged the production of lead. Large as our output is, however, it is not in general sufficient to satisfy our domestic demands Imports of lead have normally exceeded our exports.

Lead has two qualities which fit it for a wide variety of uses. It is a very soft metal and it is not rusted or corroded by contact with water. Therefore it has a very large use for water-piping and roofing One-fifth of the entire output, however, is transformed into white lead, to be used in the manufacture of paint. Lead thus used is gone forever; like coal, its properties are destroyed in the rendering of one service. In this respect it is unlike copper. A large part of the copper that has been produced during the past fifty years is still in existence. Much of it will be preserved for our descendants. The American Telephone and Telegraph Company owns more than twenty million miles of copper wire. Copper in manufactured form is by one and the same process used in the present and stored for the future. Germany, during the war, simply transferred her stored copper from one use to another use. No small part of it has been since retrieved in the form of salvage from the battlefields and will yet serve for other uses.

These are matters of very great importance. The world's reserves of copper are not adequately known, nor do we know just what improvements are yet to be made in the extracting of copper from its ores. But there are many competent authorities who think that if the world's use of copper continues to grow in the future as it has in the past, the copper mines of the world may be exhausted within a period of fifty years. If such proves to be the case, it is certain that copper will be more and more expensive and that the electrical industries will have to turn to aluminum, zinc and other more or less satisfactory substitutes for copper conductors.

Zinc, on the other hand, is a material of which there seems to be large and adequate supply. In fact, for many years a large part of the zinc obtained in connection with silver and lead was viewed as a detriment. This is partly because the supply of lead has been so large that the price has been low, and partly because the presence of zinc in high proportions interferes with the recovery of the other metals from the ore. It is fair to say that a large part of the zinc mined in the last thirty years has been wasted or got rid of by some means or other. During the war there was a phenomenal increase in the price of zinc — from double to treble The large German output was no longer available to the allied nations, and the burden of supplying them and the rest of the world fell on the United States. Old and abandoned zinc smelters, even those of antique design, were brought into use again. After the war there was, of course, a reaction and a reduction in prices. The United States is now in a position to produce more zinc than the whole world can use. From the point of view of the conservation of the world's resources, it would be well if zinc could be used to replace lead and copper, so far as is practicable.

THE WORLD'S PRODUCTION AND CONSUMPTION OF ZINC

(Smelter output, in metric tons of 2,204 6 pounds)

(From figures compiled by the *American Bureau of Metal Statistics*)

Country	Production	Consumption
United States	457,649	395,600
Belgium .	178,124	124,900
France and Spain	101,443	139,500
Germany	97,300	183,500
Great Britain	49,376	170,700
Holland . .	23,255	10,800
Italy .	18,586	24,500
Unspecified	485,182	239,100
The World	1,410,915	1,288,600

Zinc is used in manufacturing white paint, in galvanizing iron, and in the manufacture of sheet zinc and brass. Before the war two-thirds of the zinc output was used in galvanizing iron.

Until recent years the United States stood second to Germany in zinc production. Today it is far in the lead, and has become also a large exporter, while Germany must import almost half her needs.

In taking stock of the world's future metallic resources, it is impossible to omit mention of aluminum. Aluminum has been aptly called the metal of the future, and the discovery of a cheap method of isolating it from the ores constitutes one of the most remarkable achievements in metallurgical history. It is by far the most abundant of metals. It has been calculated that it constitutes as much as 8 per cent of the earth's crust. Iron, the next most abundant element, comprises less than 6 per cent. Many rocks contain from 20 to 30 per cent aluminum.

A YEAR'S PRODUCTION OF ALUMINUM

Before and After the War

(In thousands of pounds)

Country	1913	1929
United States	66,100	224,930
France	33,600	63,945
Switzerland	22,400	45,643
Great Britain	22,400	30,649
Canada	13,300	90,610
Austria-Hungary	11,200	8,158
Norway	5,600	64,258
Italy	2,000	16,257
Germany		83,128
Total	176,600	627,578

The economic possibilities of this metal have only recently been comprehended. Pure aluminum is a beautiful white metal with a slight bluish tint. Put alongside silver its color does not appear appreciably different. But common silver, alloyed with copper, has a yellow tinge not found in aluminum. Aluminum is not so soft as tin, and by cold drawing or rolling it becomes nearly as hard as brass. It is quite a fusible metal, and melts at about the same temperature as zinc. It loses little of its weight in heating, even by a forge fire, and it possesses the highest tensile strength. Aluminum is not subject to rust, and in this respect holds the advantage over steel. Its mechanical possibilities appear almost unlimited.

Aluminum is furthermore one of the most malleable of the metals It can be beaten out into leaf, and can be forged and rolled as easily as gold or silver. It can be drawn out into the finest wire. It is a good conductor of electricity, and it is likely eventually to displace copper for this purpose. Water has no action on aluminum, — boiling does not reduce its weight. It is also unaffected by air. By experiments it has been found to resist oxidation at a heat greater than that required for the assay of gold. Sulphuric acid, diluted in the proportion at which it will attack most metals, does not act upon aluminum. Neither is it attacked by nitric acid at the ordinary temperature.

Consider the future possibilities of this metal, by nature the most abundantly supplied of all, which has the strength, lightness and malleability of silver, which does not corrode, which has a high electrical conductivity. Why is it that it has not held a more important place among our economic materials? The answer is, of course, the expense of extraction. The greater part of aluminum is found in compounds called silicates, and to extract the metal is costly. It was not until 1886, when Charles M. Hall patented a process for isolating aluminum by the use of the electric current, that it became a commercial possibility.

The ore from which aluminum is obtained is aluminum oxide, called "bauxite." In the United States it has long been mined in Arkansas, Georgia, Alabama and Tennessee. The largest European deposits are in southern France. It is known that bauxite of good quality exists in South America, as well as in Africa and Asia. The lower the percentage of silica in the bauxite, the more available it is as aluminum ore. The aluminum thus far manufactured has been obtained very largely from bauxites low in silica. It is chemically possible, however, to produce aluminum from low-grade bauxite ores, and even from the clays and shales, found almost anywhere, that carry high percentages of aluminum. The only obstacles are the high costs of treating such ores, the world's largest single mineral reserve.

The precious metals now demand our consideration. Here we find the United States surpassed only by the Transvaal. Until recently, however, the United States has occupied first place. The supreme position of this country in the past has been due to the fact that it is one of the few countries which has been a great producer both of gold and silver Indeed, in no other continent but America are there to be found rich deposits of gold and silver so interlocked with each other that the cost of extraction for each is considerably reduced.

From the beginning of the science of political economy the question has continually been propounded, What is the real value to a country of its precious metals? Is a nation richer because its gold yield is abundant? The mercantilists of the seventeenth and eighteenth centuries indeed argued that gold and silver were the most important of all commodities, that the commercial policy of nations should have for its principal purpose the maintenance of a large stock of gold or of silver. And so we witnessed an era of high protective tariffs, of liberal bounties and subsidies to home industry, of laws seeking to restrict colonies from purchasing finished goods from merchants in rival manufacturing countries.

But in the liberalistic period, following the publication in 1776 of Adam Smith's epoch-making work, "The Wealth of Nations," mercantilism declined. Statesmen were convinced that it was not masses of gold or silver that contributed to the well-being of the people, but rather the sum total of the goods capable of satisfying their people's wants and needs. The principal use of gold is not found in the arts; its primary service is to furnish the counters of exchange. What real difference did it make whether the number of these counters was large or small? Assuredly gold does not to any large extent increase man's goods, the things necessary to satisfy his wants. And so, how is it that the great gold production of the United States can be said to contribute to its wealth, to minister unto its industrial welfare?

The answer is that no nation lives by itself; it cannot be isolated in trade from its neighbors. Were the United States virtually self-sufficing and without foreign trade connections, its vast silver and gold would indeed contribute little to its wealth. But gold mined in the United States permits the purchase of goods from abroad without the sacrifice of other materials The gold-mines of California and Colorado yield a mortgage upon the labor of the coolie in China, of the white man in Europe, of the black man in the tropics. A country without the precious metals must continually exchange the other products of its labor and its capital for the so-called "sterile wealth" of other countries. And that is why we cannot omit mention of America's gold when taking stock of its natural resources.

We have finally to consider the mineral fertilizers. Particularly important are these because they directly concern the country's food supply. The more important elements necessary to sustain plant life are the following: hydrogen, oxygen, carbon, silicon, calcium, nitrogen, potassium and phosphorus. Of these, five are so abundantly supplied by nature that for the present man need not seek to inventory his stock. Hydrogen and oxygen are constituents of water, and by plant action carbon is continually being taken from atmospheric carbon dioxide and returned to the air. Calcium is found in large quantities in the soil, and may furthermore be obtained from limestone. And silicon is one of the most abundant elements of all.

The elements of principal concern to man, so far as his food supply is concerned, are nitrogen, potassium and phosphorus. In another chapter there is an account of the nitrates. There it is shown that, by the cultivation of the legumes whose roots bear bacteria capable of extracting nitrogen from the air, soils deficient in this element may be restored. It is also shown that by a more careful use of a by-product — ammonium sulphate — further plant nitrogen may be obtained. In the future the sewage of cities, rich in nitrates, will undoubtedly no longer be wasted by turning it into rivers. Finally, the chemist, spurred on by the needs of the war, has found a cheaper method of drawing upon the nitrogen of the atmosphere. We need not, therefore, seriously concern ourselves with the adequacy of mineral nitrates, such as are today found in the deposits of Chile.

Neither do we find that the capacity of man to feed his kind is likely to be limited by inadequate supplies of potassium. The crust of the earth's surface contains about 2 5 per cent of this element, and in many rocks several times this proportion is found. And by natural processes the potassium has been extracted from the original rocks and segregated in many places in a form immediately available for fertilization. Such, for instance, are the enormous potash deposits of Germany and of Alsace. If in the future such deposits as these should become exhausted, recourse may be had to the potash richly deposited in the original rocks.

But in respect of phosphorus the situation is entirely different, and we are justified in regarding this as the crucial element limiting the future productivity of our soils. Phosphorus is a food essential alike to man and plants. Experiments have shown that when animals are deprived of phosphorus they cannot live more than a few months. For a time the flesh would take some of the phosphorus from the bones, but at length a time is reached when the bones can no longer supply sufficient quantities.

In the past great quantities of phosphorus have been stolen from the land. First of all there is a great deal of phosphorus in grain. Wheat contains over a third of one per cent of phosphorus. So, when a crop of grain is sold from the farm, the owner is not selling merely replaceable plant food; he is also parting with mineral phosphates. Wherever grain is grown continuously without crop rotation, the soil is bound to be deficient in this element. Western fields cropped for fifty years have been found to have lost one-third of their phosphorus, and in many of the Eastern States the addition of phosphate fertilizer has long been customary.

A second loss of phosphorus occurs through leaching and erosion. That such loss must occur is shown by examinations of the soil. Numerous experiments have proved that the loss of phosphorus in the land was greater than could be accounted for by calculating the amount borne away with the crops Finally, a great deal of phosphorus is lost in the stables and barnyards through failure to preserve animal manure. In the future farmers must learn to prevent this loss.

The value of these enormous deposits was well recognized even in the time of the Incas of Peru. To kill the sea fowl, or even to gather their eggs, was then a crime punishable by death

Mineral phosphates have then been formed in prehistoric ages by the excretion of birds and animals. The United States has been beneficently endowed by nature with these rock phosphates. With its superiority in the natural deposits, the United States has inevitably been required

Photo from American Museum of Natural History

A COLONY OF GUANO BIRDS ON SOUTH GUAÑAPE ISLAND, PERU

Such are the wastes of phosphorus. What now are its sources? The chief are those deposits segregated by the natural processes of nature. Many and complex are the ways in which these processes have operated. Consider, for instance, the guano deposits on the islands lying off the west coast of South America. First of all, the phosphorus disseminated from the original rock becomes a constituent of certain plants and animals. These become the food of fishes, which in turn are eaten by sea birds. The guano deposits are then formed by the excretion of sea birds.

to furnish a large part of the world's supply of phosphate rock. The question therefore arises as to whether the United States' supplies are adequate to meet these demands. In this country deposits of mineral phosphates are to be found in both the Southern and the Western States. But the high-grade phosphates are limited to a few of the Southern States. In those states, it is estimated, there are reserves of nearly 350,000,000 tons of phosphate rock; enough to last, at the present rate of consumption, for over a hundred years. But, of course, the rate of consumption is bound to increase rather than decrease.

In the Western States, however, there are reserves which are estimated to amount to the enormous total of five and one-half billions of tons; enough to last, at the present rate of use, for fifteen hundred years. As a matter of fact, the present limitations upon the supply and distribution of phosphates come from the high cost of shipping so heavy and bulky a commodity, together with the cost of the sulphuric acid required to convert the raw ground rock into soluble acid phosphate

An important source of phosphate, not available to the United States even if it were needed here, is basic-slag, a by-product of the manufacture of steel from the phosphoric iron ores of Germany, France, and other European countries.

THE WORLD'S GREAT PRODUCERS OF PHOSPHATES

(Figures in metric tons Natural phosphates for the year 1928; basic-slag, for the year 1927)

Country	Natural Phosphates	Country	Basic-Slag
United States	3,579,800	Germany	1,742,000
Tunis	2,789,000	France	1,332,000
Morocco	1,337,100	Belgium	887,000
Algeria	817,100	Great Britain	675,000
Ocean Island	552,000	Luxembourg	571,000
Egypt .	200,600	Saar region	304,000
France	193,000	Poland	23 000
Paumotu Islands*	131,300	Sweden	9,500

* Exports

Even though the world's supplies of phosphorus are such as to cause no concern for the immediate future, it would be wrong to conclude that we should exploit them heedlessly and thoughtlessly, without regard to the future interests of the world. For, aside from coal and iron, the mineral fertilizers are the most important of all nature's mineral gifts to man.

From the standpoint of nature's beneficence, the people of the United States have only cause for self-congratulation. But it cannot be too strongly emphasized that these gifts are the mere accidents of creation; in the present régime of man they cannot to any considerable extent be repeated. A nation which draws upon these resources without foresight is like the spendthrift who barters future capital or the sake of present income.

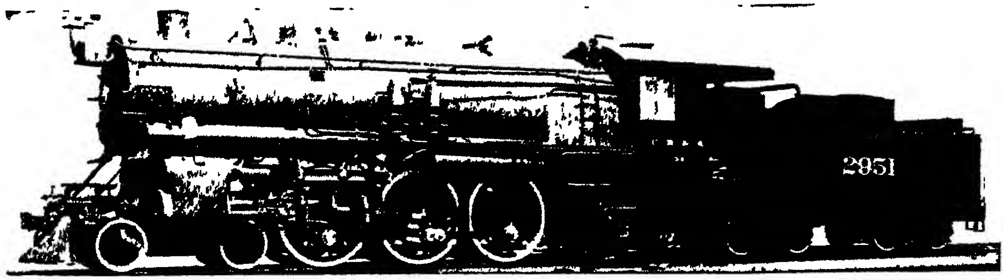
As the original chemical elements cannot be created by man, neither can they be destroyed. Do all in his power, man cannot add or subtract a single atom from the physical mass of the universe. But he can destroy utilities; he may so change combinations and forms that their capacity to gratify wants will be lessened.

It is not then from the principle of the inviolability of matter, but rather from that of the destructibility of utilities that the true policy of conservation should proceed. The use of metals for some purposes does not mean their withdrawal from future use. It is not always a question of wresting these materials from nature; it is often primarily a question of the use to which they shall be put. The utilization of lead for paints means that after one act of consumption its utility to man is destroyed. When devoted, on the other hand, to the making of water pipes, the material is available for future use. Copper devoted to chemical purposes is rarely available more than once; for other uses it can be drawn upon again and again. And so likewise with zinc.

Most of the minerals may be utilized for several purposes True conservation policy again demands their use for the most indispensable services. Petroleum for fuel or power is not absolutely indispensable; for both purposes alcohol may very well be substituted. So far as economically possible, petroleum should be saved for lubricating purposes and for the other uses for which it has no adequate substitute. Likewise either copper or aluminum may serve for conducting electricity; but if future chemical discoveries should render aluminum the more common metal, the use of copper for this purpose should be abandoned. And likewise with the nitrates; conservation of sewage and manure should relieve as far as possible the pressure upon our mineral deposits.

In these and other ways the principle of utilizing first that which is at present the cheapest or the most available is being modified. The thoughtful nation must consider not merely what is for the present the most economical, but what is also likely to be dearest in the future.

SOME BIG AMERICAN LOCOMOTIVES

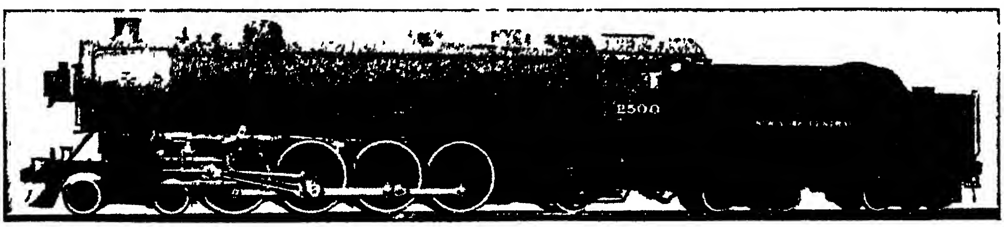


Courtesy Baldwin Locomotive Works

TYPICAL PASSENGER LOCOMOTIVE OF THE PACIFIC OR 4–6–2 TYPE

Courtesy Baldwin Locomotive Works

AMERICAN 2–10–2 OR SANTA FÉ TYPE OF LOCOMOTIVE



Courtesy American Locomotive Co

MOUNTAIN TYPE LOCOMOTIVE FOR HAULING HEAVY PASSENGER EXPRESS TRAINS

This engine weighs over 170 tons and can exert a tractive effort of over 50,000 pounds

Courtesy Baldwin Locomotive Works

THE MOST POWERFUL LOCOMOTIVE EVER CONSTRUCTED

While its total weight (844,000 pounds) is not quite as great as some others of its type, its tractive effort (166,000 pounds) is 6000 pounds greater than that of the next largest locomotive. Note drivers on tender

Courtesy American Locomotive Co

THE LARGEST SINGLE LOCOMOTIVE EVER BUILT

This monster weighs 684,000 pounds and can exert a tractive effort of 147,200 pounds.

BUILDING THE IRON HORSE

The Immense Industry that has helped to Solve the Problems of Land Transportation

HOW MODERN LOCOMOTIVES ARE CONSTRUCTED

NO other product of the brain and hand of the engineer excites and retains a greater amount of human interest than does the locomotive What boy does not at some time or other aspire to be a locomotive engineer? What man is so old that he does not pause in admiration and awe as one of these monsters thunders by, lashing its long tail as it flies around the curves? At night it is even more impressive, when with its one great eye peering through the gloom it goes tearing along its iron path Surely here is the actual embodiment of all of the imagined, fire-breathing, terrible creatures of the ancients.

As the steamship bridges the distance between continents, so does the locomotive make their remotest inhabitants near neighbors Its early history is closely connected with that of the steam road carriage, and the return to motor trucking over ordinary roads is interesting, due to the improved reliability of the gasoline engine and the success of its application on a large scale to freight problems in the Great War. While the work thus performed in France and America supplemented that of the railroads and relieved their congestion, and while the commercial possibilities of air-service between great cities are partially realized, there is no reason to believe that the locomotive will be deposed as the "king of transportation" for many years to come

The idea of laying a special roadway for the wheels of loaded vehicles goes back to the time of the Romans who were in the habit of paving that portion of the road over which the wheels passed with blocks of stone set in parallel tracks.

The very same method was frequently adopted in the early days of coal-mining in England where the coal was taken away from the mines in carts drawn by horses About 1630, however, a man named Beaumont laid down wooden rails for this purpose and by the end of the eighteenth century "tramways" of wooden rails with rounded upper surfaces, on which the grooved rims of the cast-iron wheels of the cars fitted, were in common use, and the economy of making the grades easy by cutting down hills, filling depressions and bridging streams was well understood. Later the wooden rails were covered with cast-iron plates, to reduce the wear, and in 1776 a tramroad was built at Sheffield by laying angle bars of cast-iron upon longitudinal wooden timbers. From these crude beginnings has grown the modern railroad with its heavy cross timbers embedded in broken stone, carrying steel rails weighing 90 to 120 pounds to the yard, and all its complex auxiliaries of switches, signals and safety devices

By the end of the eighteenth century the steam-engine had become a real factor in industry and several attempts had been made to apply it to road carriages. The credit for making the first successful locomotive running upon fixed rails belongs to Richard Trevithick, who completed in February 1804 a "locomotive" engine to draw coal on the Pen-y-darran road in South Wales. Before describing a few of these early engines it may be well to examine the principal features of a modern locomotive, for the elements of the locomotive of today are the same as those of the very first to "turn a wheel"

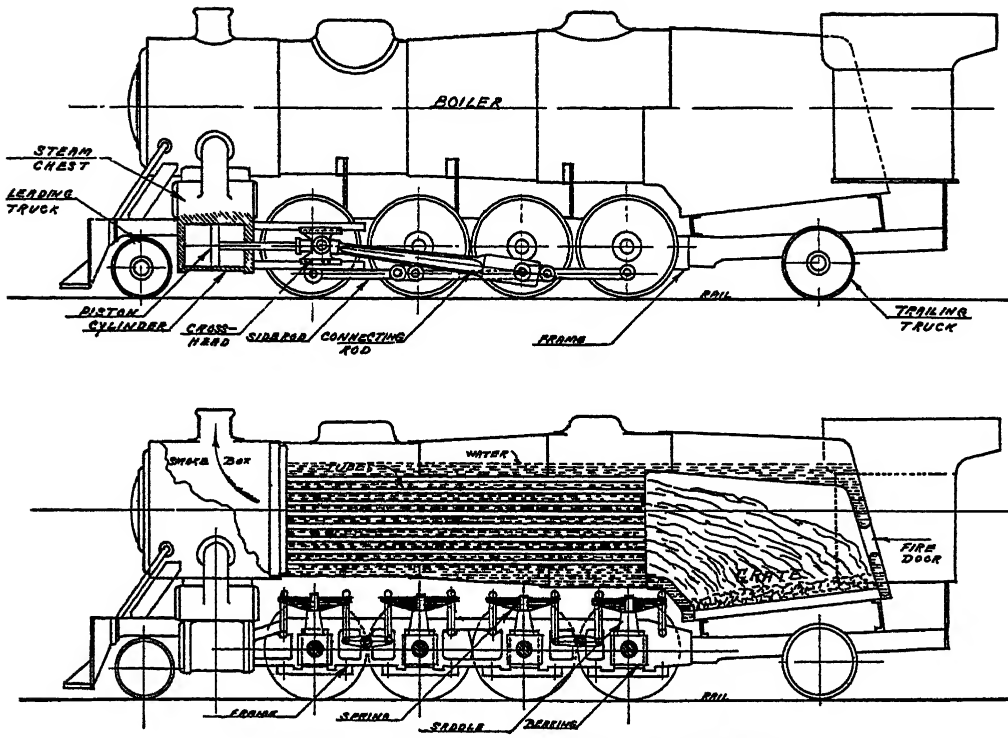


DIAGRAM SHOWING PRINCIPAL PARTS OF A LOCOMOTIVE

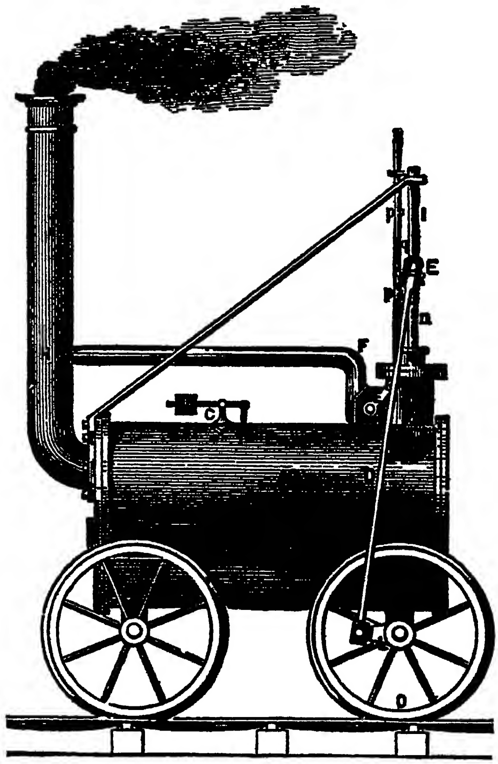
In the upper of the two diagrammatic views of a modern heavy-service locomotive, the boiler is seen to be carried upon the frame, which in turn is supported upon the axles of the wheels through the medium of springs. A heavy cast-iron saddle connects the forward end of the boiler to the frame and also carries the cylinders of the engine. In the figure the wall of the cylinder is cut away so as to show the circular piston which moves backward and forward in the cylinder. Steam is admitted to the steam chest by a valve controlled by the engineer. Inside of the steam chest is another valve, not shown, operated from one of the axles, and which, when the axle turns, admits steam first to one and then to the other side of the piston, permitting it to escape or "exhaust" when it has forced the piston to one end or the other of the cylinder. The piston is fastened to the crosshead and compels it to move backward and forward in its guides The crosshead is connected to a crank-pin in one of the driving-wheels, and this motion makes that wheel rotate in much the same manner that the treadle of a sewing machine produces rotary motion in its driving-wheel. Where more than one set of driving-wheels is used, in order to obtain greater contact with the rail all of those on one side are coupled together by means of side-rods which compel them to rotate in unison. There is an engine on each side of the locomotive coupled to the same set of drivers, but the crank-pins are set 90° apart so that the two engines are never at the end of the stroke at the same time, and one of them is therefore always in a position to start the locomotive. The mechanism for operating the valve in the steam chest permits the change of the flow of steam in order to reverse the direction of movement of the locomotive when it is wished to go backward.

In the lower figure of the diagram, the driving-wheels are removed so as to show how the great weight of the machine is carried. The boiler, as has been noted, rests upon the frame. The frame in turn is suspended by links from the springs.

The springs are supported by the saddles which straddle the frame and rest upon the axle bearings The axle bearings finally transmit the load to the wheels and thence to the rails In American locomotives, where there are several sets of drivers, the adjoining ends of the springs are connected to opposite ends of a common lever, as shown in the figure, thus giving greater elasticity to the connection between the frame and the axle This permits the great machine to move over uneven places on the track without bringing undue strain upon the frame or boiler. When the locomotive is very long, as in that shown, auxiliary trucks must be provided at one or both ends; these are known respectively as "leading truck" and "trailing truck" Sometimes they are mounted on two wheels, sometimes on four, and the frame which carries the axles is arranged to swivel around a center pin, so as to permit the locomotive to negotiate curves.

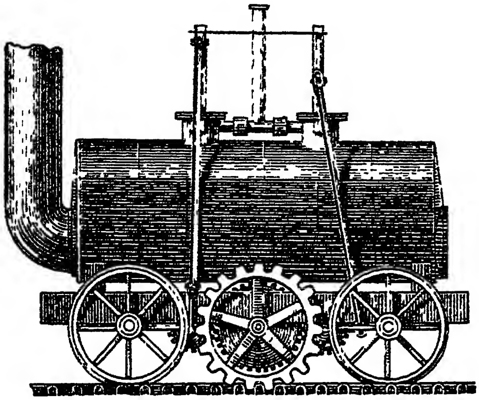
The lower figure of the diagram also has a part of the boiler shell removed so as to show the fire-grate in the fire-box and the tubes which carry the hot flames and gases from the latter to the smoke-box at the forward end of the boiler, whence it escapes up the chimney or "stack," as it is commonly and incorrectly called. The water which surrounds the tubes and fire-box is converted into steam by the hot gases and passes to the engine After being used there, it is allowed to escape through a pipe up the chimney, thus making a very strong draft through the tubes and grate and stimulating the combustion of the coal amazingly. If it were not for this the modern locomotive would not be nearly so powerful for its size.

The principal parts of a locomotive, therefore, are the boiler, the frame which carries it, the engines (which include the valve mechanism), and the driving-wheels. Contrasted with some other forms of the steam engine, the locomotive is comparatively simple, and at first sight one may wonder why it took so long to develop it. It should be remembered that the conditions under which it works are vastly different from those under which stationary land or even marine engines operate. Because stationary engines always rest upon solid foundations, and even marine engines have fairly stable supports. But here is an engine over 70 feet long and 16 feet high, weighing over 300 tons, with a boiler nearly 9 feet in diameter carrying steam at 200 pounds pressure to the square inch, mounted on wheels over four feet apart and running on a steel rail which, compared to its own huge bulk, looks like a mere ribbon, which not only stays on the track but draws heavy loads at high speed up hill and down with much more certainty and with less trouble than is given by most machines.



THE FIRST SUCCESSFUL LOCOMOTIVE: TREVITHICK'S, 1804

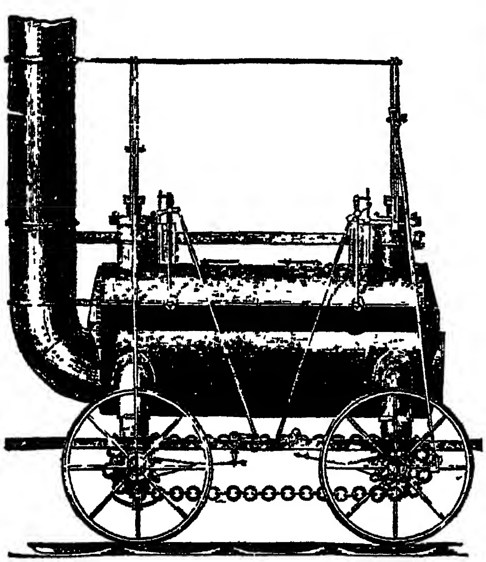
Trevithick's locomotive, according to the best of varied accounts, looked somewhat as shown in our illustration. The boiler was of cast-iron with an internal furnace, the products of combustion being returned to a chimney at the same end as the fire-door. The engine was placed vertically and the connecting rods, *D*, attached directly to cranks, *L*, on the driving axles. The exhaust steam was allowed to escape



BLENKINSOP'S LOCOMOTIVE, 1812

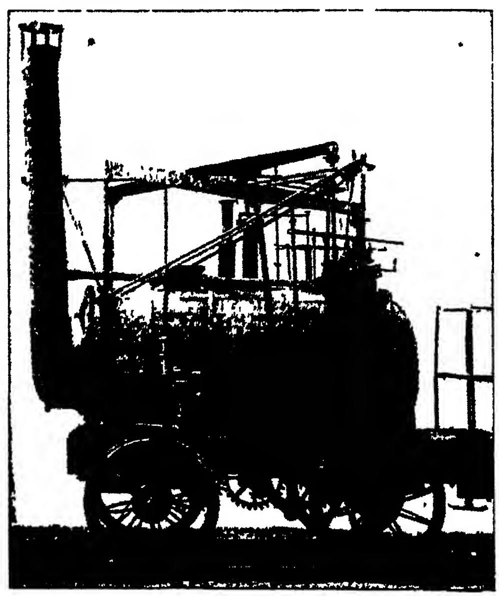
up the chimney so as to increase the draft and Trevithick depended upon the friction of the driving-wheels upon the rails to secure sufficient tractive power. The steam pressure was 40 pounds to the square inch so that it was a "high pressure" engine. A safety valve, *C*, prevented undue pressure in the boiler. The engine worked well, but was not a financial success.

The next successful attempt at a steam locomotive was that made by Blenkinsop in 1812. This engine, as shown, had two cylinders, eight inches in diameter, placed vertically like those of Trevithick's machine. The connecting rods, however, operated gear-shafts which in turn drove a large, toothed wheel that engaged the



STEPHENSON'S KILLINGWORTH ENGINE, 1816

ends of the cross ties. The supporting wheels did no driving. Blenkinsop's machine was followed in 1813 by Blackett's "Puffing Billy," which followed much the same lines in general structure but secured tractive effect through the supporting wheels, as in Trevithick's original invention. In the meantime, George Stephenson, the engineer of the Killingworth Colliery, had been working on the problem and in 1814 produced his first engine. The "Blucher" had a boiler 34 inches in diameter and 8 feet long, with a fire tube 20 inches in diameter. The cylinders were 8 inches in diameter with 24-inch stroke. It did



BLACKETT'S "PUFFING BILLY," 1813

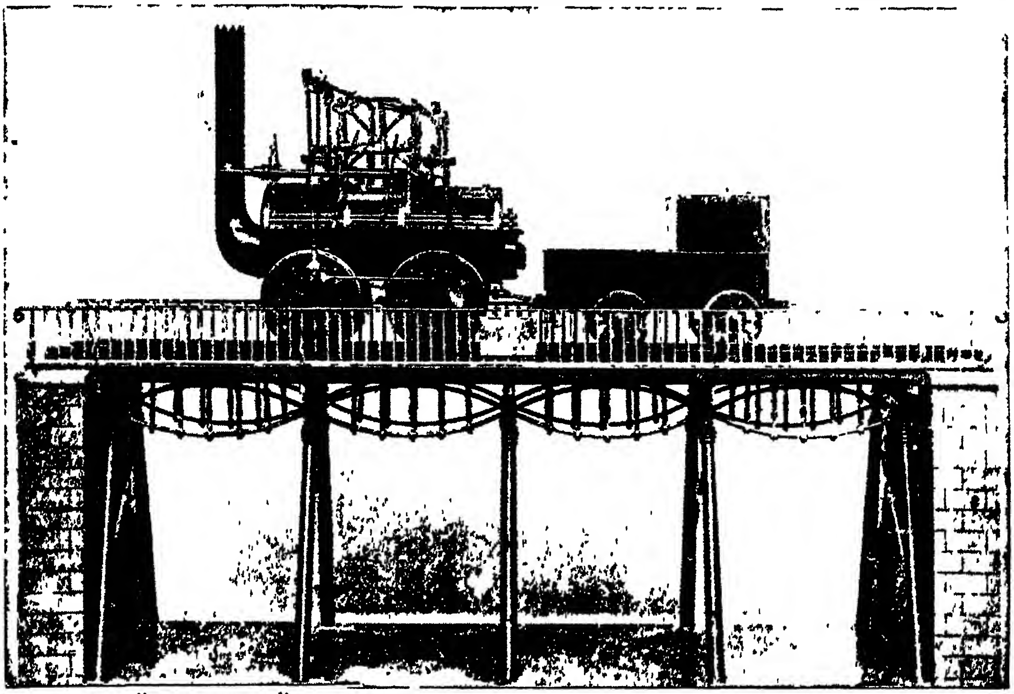
not differ very greatly from some of its predecessors but in Stephenson's second engine, built in the following year, he began to show that originality which won for him the distinction of making the locomotive a commercial success. In this engine the connecting rods were attached directly to all four wheels and the two axles were coupled by connecting rods working on cranks inside the bearings. The rods were afterward replaced by chains, as shown in the illustration. In a third engine very similar to the second, the boiler was carried on steam cylinders, thus foreshadowing the modern arrangement of spring support.

THE RACING MONSTERS THAT THUNDER ACROSS THE CONTINENT

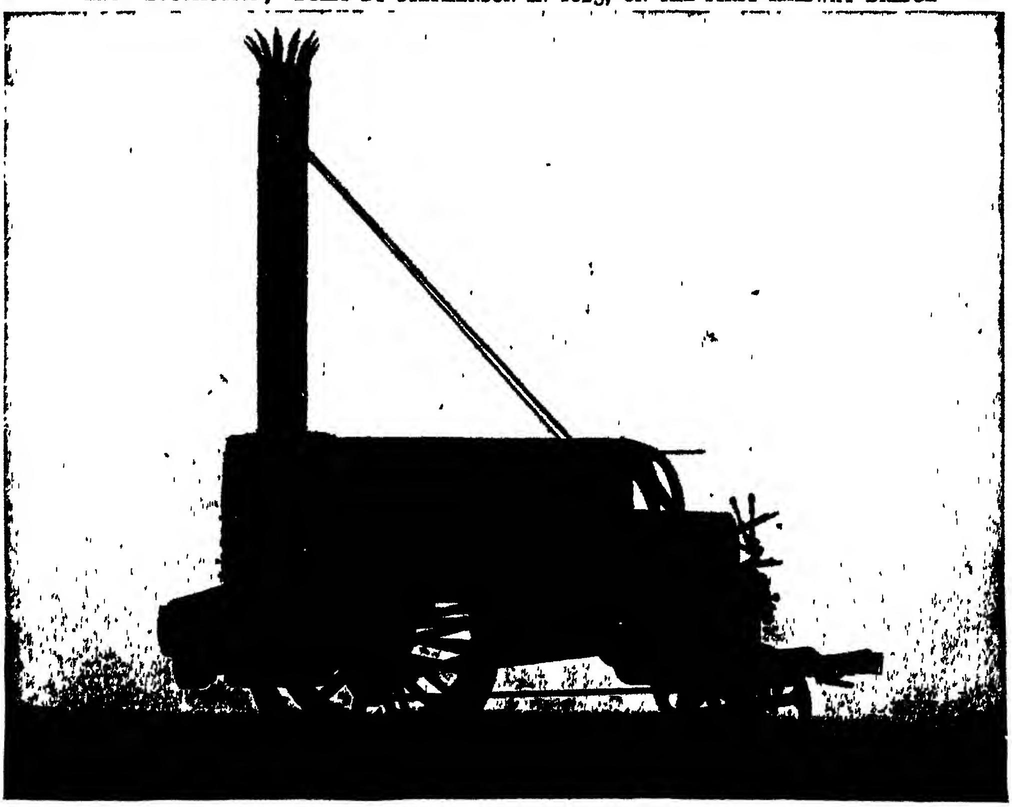
Courtesy *Scribner's Magazine*

RIVAL FAST TRAINS COMPETING TO THE LAST OUNCE OF DRIVING POWER IN ORDER TO COMMAND THE THROUGH TRAFFIC

EARLIEST TYPES OF RAILWAY ENGINES



THE "LOCOMOTION," BUILT BY STEPHENSON IN 1825, ON THE FIRST RAILWAY BRIDGE

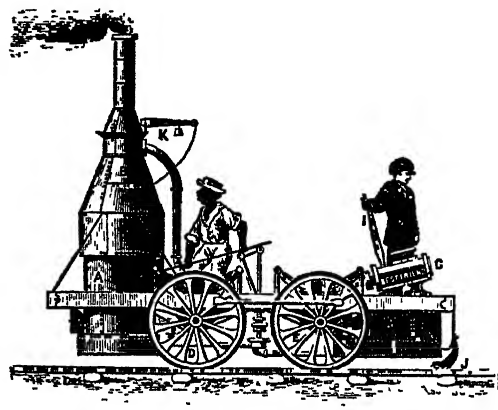


THE PRIZE ENGINE "ROCKET," BUILT BY STEPHENSON IN 1829

All of these locomotives were designed for drawing coal cars at low speed for privately-owned collieries and long after they were admittedly successful at such work passenger cars were still pulled by horses, and it was only by persistent arguments that Stephenson got permission to construct three locomotives for the new Stockton & Darlington Railroad, of which he was appointed chief engineer in 1823, and which was built with the idea of using horses as tractive power. The first of these, the "Locomotion," was not unlike former engines but it had outside side-rods. The boiler was four feet in diameter and 10 feet long, the two vertical cylinders being 10 inches in diameter. The drivers, it will be noted, were connected by side-rods as in the modern locomotives. The engine weighed 6½ tons It was accompanied by a tender for carrying coal and water. The Stockton & Darlington was the first regularly operated railroad to use locomotives for hauling passengers and freight, and horses were soon discarded.

The supremacy of the locomotive was finally and fully established by the competition inaugurated by the Liverpool & Manchester Railway to decide what method of traction was best for this new road and offering a reward for the best solution. The entire plan was opposed, of course, by coaching companies and owners of land along the right of way. Stephenson, who had been appointed chief engineer of the road, brought down abundant ridicule upon his head by asserting that he could build a locomotive that would run 20 miles an hour. During the debate for a charter before the House of Commons, he was asked by a member of a committee of that body: "Suppose now one of your engines to be going at the rate of 9 or 10 miles an hour and that a cow were to stray upon the line and get in the way of the engine, would that not be a very awkward circumstance?" To this he replied: "Yes, *very* awkward *for the coo*." And when asked if men and animals would not be frightened by the red-hot smoke pipe, he replied with rare good sense: "But how would they know that it was not *painted?*"

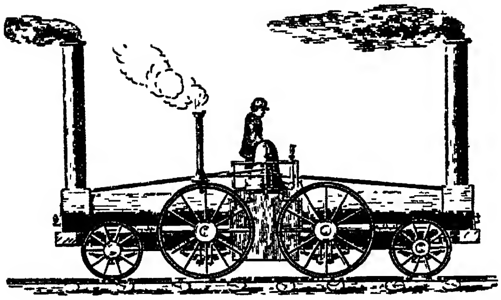
For this competition, which took place in October 1829, Stephenson built the "Rocket," which not only beat all competitors but actually ran at the rate of 25 miles an hour on the trials, and two days after drew 13 tons of freight at a speed of 29 miles an hour. The "Rocket," which weighs only 4½ tons, has a boiler, built with tubes in much the same way as modern boilers, 6 feet long and 40 inches in diameter. The engine is set at an incline and is coupled directly to a single large driving-wheel The exhaust was blown up the stack through tapered blast pipes. It embodied, therefore, practically all of the features essential in a successful locomotive, and ran for many years.



THE "BEST FRIEND," 1830

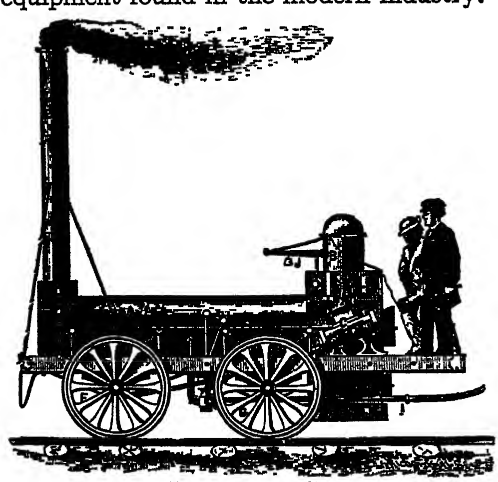
The first attempt at the commercial use of the locomotive in America was made in 1829 by the Delaware & Hudson Canal Co. when they imported the "Stourbridge Lion" from England to run on their 16-mile line from Carbondale to Honesdale, Penn. The rails proved to be too light and it was soon laid off.

The first locomotive built in America was a small model made by Peter Cooper and successfully tried out on the Baltimore & Ohio Railroad. The boiler tubes were made of gun barrels and the engine developed only 1.43 H. P This was the beginning, and in a short time there appeared, in the order named, the "Best Friend" (1830), the "West Point" (1831), the "South Carolina" (1831), the "De-Witt Clinton" (1831), the "Atlantic" (1832), and "Old Ironsides" (1832).



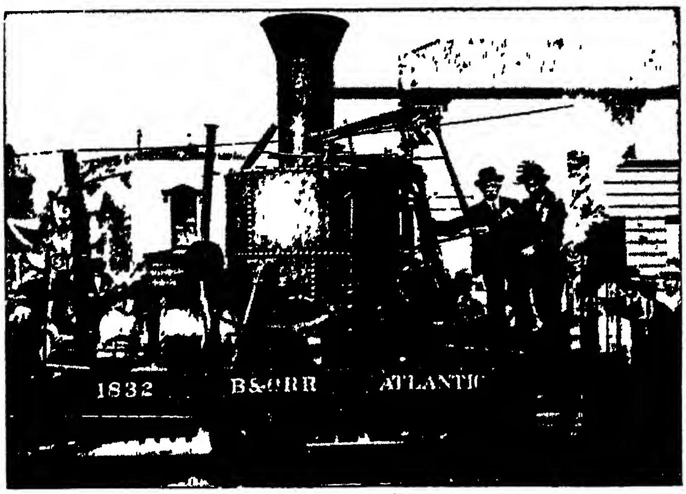
THE "SOUTH CAROLINA," 1831

The last named was the first engine built by Matthias W Baldwin, the founder of the great Baldwin Locomotive Works in Philadelphia. The development of the locomotive was now well under way in America and special plants, some of which were destined to grow to world-famous institutions, began to take the place of what at first had been small, primitive general machine shops, without any of the special equipment found in the modern industry.



THE "WEST POINT," 1831

Many curious and interesting arrangements of the essential parts of the locomotive were tried out by rival makers before a definite type of machine was evolved. The boiler had now been lengthened and the engine cylinder placed horizontally at the forward end There were two driving-axles and the connecting rod of the engine was coupled directly to one of the driving-wheels. The drivers were connected by side-rods. The fire-box was still narrow enough to go between the drivers, and a leading truck had been found necessary because of the length of the boiler and to aid the locomotive in negotiating curves. The several auxiliary fixtures such as bell, whistle, sand-box, etc., had all been added by this time and the weight had gone up to 30 tons. "Engines" of much greater size and power have since been built, but the general characteristics of the modern locomotive had been fairly well settled by the year 1850.



THE "ATLANTIC," 1832

As the early locomotives, like steamships, had specific names, now usually replaced by serial numbers, to identify them, so the types which were called forth by the different requirements in railroad development came to be known by different names. Thus the locomotive of 1850 or thereabouts, still to be seen doing light passenger service, with two sets of drivers and a four-wheeled forward truck, was generally known as the "American" type. In 1866 the Baldwin Locomotive Works built the first of a new type of freight locomotives for the Lehigh Valley Railroad, which had just been formed by consolidating several small roads, and the name "Consolidation" was given to this series.

THE drawings on the page opposite show accurately the relative sizes of the locomotives, being drawn to the scale of $\frac{1}{16}$ inch to the foot, placed in spaces of equal size. Types are named according to wheel arrangement. This is emphasized by omitting valve gear, brakes and all unnecessary details.

1831 — "DE WITT CLINTON" and train of 3 coaches — length less than Atlantic type locomotive.
1848 — "GOVERNOR PAINE" an early aspirant for speed honors — 1 mile in 43 seconds.
1863 — CIVIL WAR locomotive — wood burner — balloon stack — weight about 30 tons.
1876 — AMERICAN type built by Baldwin — exhibited at Centennial Exposition — 36 tons. Diamond stacks — as shown at right — were the general practice in the 70's and 80's. Note end sections showing how increase of both driving-wheel diameter and boiler diameter heightened the locomotives and how the fire-box is *lower* over trailers in modern locomotives.
1893 — AMERICAN type — "999" — exhibited at Chicago World's Fair — held world's record for speed — 1 mile in 32 seconds — engine weight 62 tons — train weight 205 tons.
1920 — PACIFIC type — "Twentieth Century Limited" — world's record for sustained high speed capacity — 11 steel cars — 810 tons — 68 miles per hour over whole division. Engine weight 135 tons.
1905 — CONSOLIDATION type — 113-ton freight hauler — best type of its day.

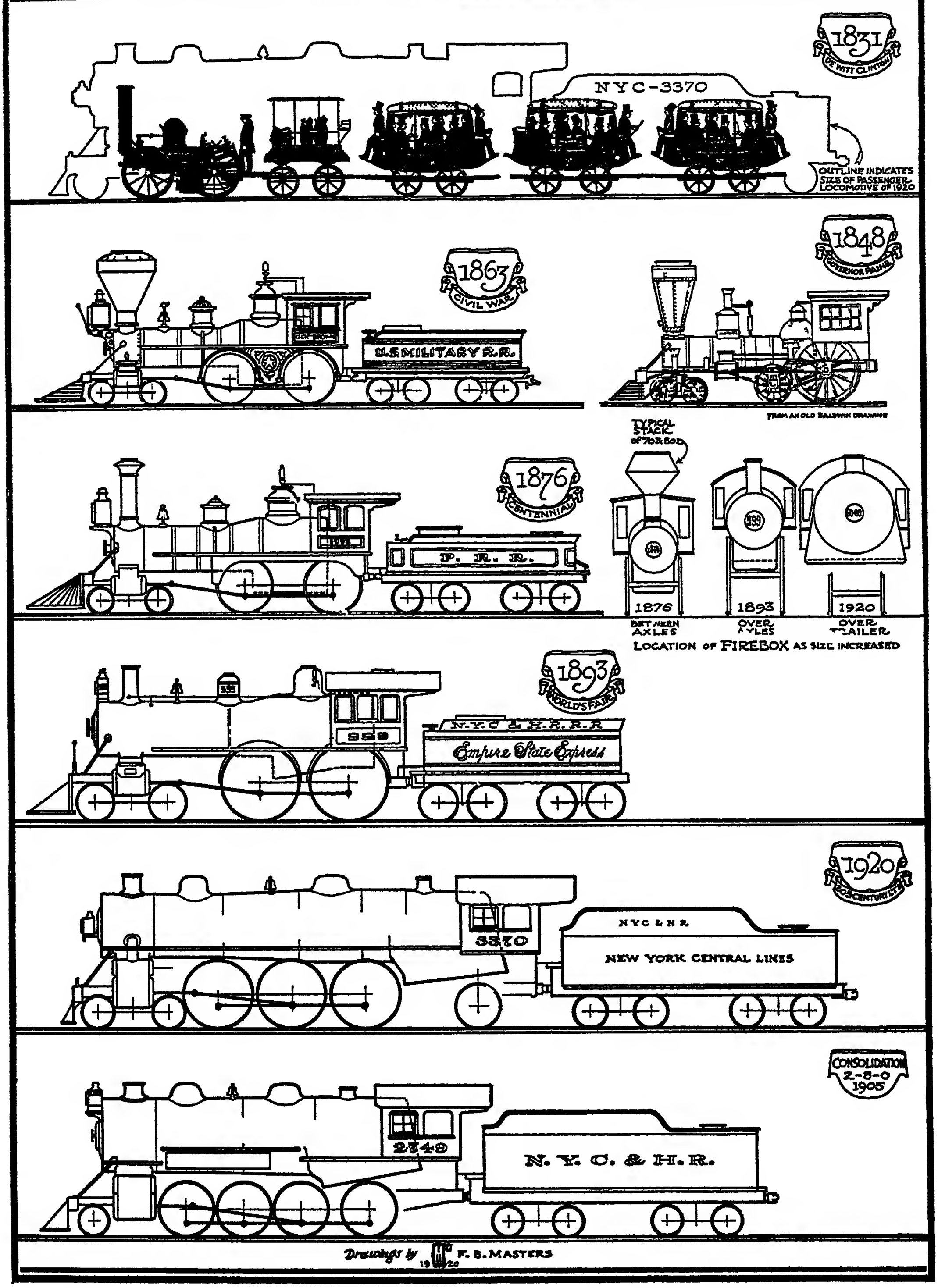
These locomotives had four pairs of drivers and a two-wheeled leading truck, and became the favorite type of engine for heavy freight such as coal. The following year the same company built the first of its new type of locomotive for heavy freight service, with three pairs of driving-wheels and a two-wheeled truck. This was known as "The Great Mogul." The term "Mogul" later came into common use to describe almost any large engine, although the first Baldwin engine of this type was not a particularly large one. The first true "Mogul" was probably built by the Rogers Locomotive Works about 1863. In 1897 Baldwin built a new style of heavy freight engine for the Nippon Railway of Japan and the name "Mikado" was naturally applied to it. These engines had four driving-wheels, a two-wheeled leading truck and a two-wheeled trailing truck under the cab. The fire-box was placed back of the drivers and over the trailing truck so that it could be widened out as far as was needed to get the grate surface required for the large boiler. In recent years it has become common practice to designate these different types according to the number and arrangement of their wheels. Thus the American types with four wheels on the leading truck, four drivers and no trailer is denoted as 4–4–0, the Consolidation type as 2–8–0 and the Mikado as 2–8–2.

This method of designation has been still further simplified by omitting the dashes.

At the end of the last century there were two types of passenger and two types of freight engines in general use. The former were of the American or 4–4–0, and the Atlantic or 4–4–2 type; the latter of the Mogul or 2–6–0, and the Consolidation or 2–8–0. The 4–6–0 was introduced in 1846 preceding the 2–6–0; and it has been since much used for freight and passenger service. It is still often built for comparatively light work. To-day a list of types and the service for which they are intended would read about as follows:

Name	*Class*	*Service*
American	4–4–0	Passenger
Atlantic	4–4–2	Express passenger
Pacific	4–6–2	Fast heavy passenger
Prairie	2–6–2	Fast passenger or freight (built only in limited numbers, 1900-1906, and now practically obsolete)
Mountain	4–8–2	Heavy passenger express
Consolidation	2–8–0	Heavy freight
Mikado	2–8–2	Heavy freight
Decapod	2–10–0	Heavy freight
Santa Fé	2–10–2	Very heavy freight
Mallet Articulated Compound	2–6–6–2 0–8–8–0 2–8–8–0 2–8–8–2 2–10–10–2	Heavy freight on heavy grades

The DEVELOPMENT OF THE LOCOMOTIVE



The last type mentioned deserves more than passing notice In America many of the railroads still have, and will continue to have, very heavy mountain grades over which immense loads of freight must be carried. As the size of freight cars and the volume of freight has increased, larger and larger locomotives have become necessary. The space available under bridges and through cuts and the gauge of the track itself impose limits to the height and width of locomotives. It was not possible, therefore, as locomotives became larger and larger, to increase the size of the cylinders, and a French designer named Mallet invented the articulated locomotive. This type usually has two complete engines under one boiler, each coupled to three or four pairs of driving-wheels. The rear engine is made fast to the boiler but the forward engine can slide and swivel sufficiently to permit the great machine to go around the curves. The "Matt H Shay," the most powerful locomotive on the Erie road, has two such engines under the boiler and another under the tender, thus utilizing the weight of the latter to create tractive force. This arrangement, however, is unusual. In these large Mallet engines high pressure cylinders drive the rear group of wheels and low pressure cylinders the forward group. These engines are therefore known as "Mallet Articulated Compounds" and represent the latest thing in heavy freight engines.

Let us now measure the progress in this important element of our civilization. The engine built by Trevithick weighed probably two or three tons and used steam at 40 pounds per square inch pressure The "Rocket" weighed $4\frac{1}{2}$ tons and is credited with having made as high as 29 miles an hour when drawing 13 tons of freight. "Old Ironsides" weighed 5 tons and made 30 miles an hour with its coaches attached By 1850 the weights of locomotives had gone up to 25 tons and by 1860 to 30 tons The heaviest locomotive exhibited at the Centennial Exposition in 1876 was a Consolidation weighing 50 tons In 1893 the famous engine of the New York Central Railroad, "999," weighing 62 tons, made the present world's record for speed when it drew a train weighing 205 tons ten miles at the rate of $112\frac{1}{2}$ miles an hour. The present world record for *continued* high speed is held by the New York Central's "3370," which in 1915 drew the Twentieth Century Limited over a division at the rate of over 68 miles per hour. The engine weighs $135\frac{1}{2}$ tons and the train consisted of 11 cars weighing 810 tons

Great as these passenger engines are, they are totally eclipsed by the modern freighters. Mikado engines weighing 150 tons are quite common, but it is the Mallet Compounds that present the most startling figures. The one already referred to is virtually three engines, since the tender wheels are also driven The combined weight of the engine and tender is 425 tons and the engine has hauled 250 cars weighing 17,900 tons on a level track. This train was one and six-tenths miles long. Monster engines of the Mallet type are becoming quite

THE drawings on the two following pages of modern American and European locomotives also show the relative sizes, being drawn to the scale of $\frac{1}{16}$ inch to the foot.

ATLANTIC — P. R R. "1067" — 120 tons — An advanced design giving great capacity for sustained pull at high speed.

PACIFIC — Erie "2509" — 135 tons — The 50,000th locomotive built by the American Locomotive Company as an experimental engine embodying the "last word" in design, materials and construction. Express passenger service.

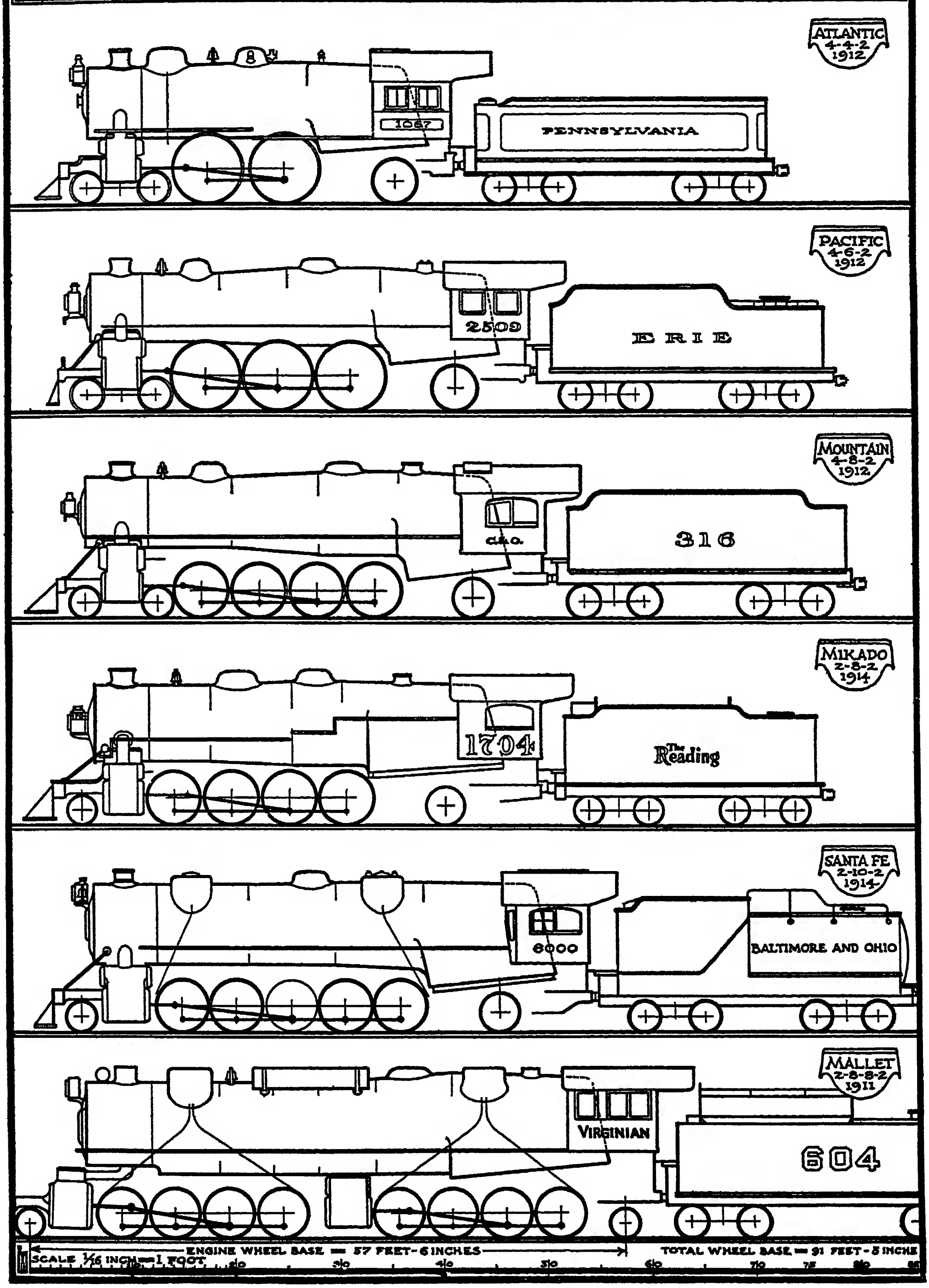
MOUNTAIN — C. & O. "316" — 165 tons — The largest and most powerful passenger locomotive in the world in 1914. Heavy passenger express service.

MIKADO — P. & R. "1704" — 166 tons — High grade powerful freight hauler.

SANTA FE — B & O "6000" — 203 tons — In 1914 the largest and most powerful locomotive in the world having all its driving-wheels in one group.

MALLET — Virginian "604" — Powerful freight pusher used on mountain grade rising 1250 feet in $11\frac{1}{2}$ miles. Driving-wheels in 2 groups

MODERN AMERICAN LOCOMOTIVES



common on mountain roads Both the American Locomotive Company and the Baldwin Locomotive Works have recently built some very heavy ones and the former has delivered to the Virginian Railway some Mallet Compounds that are said to be the heaviest locomotives ever constructed These are of the standard Mallet type with two complete sets of engines under one boiler The tender is not driven. The important characteristics of one of these locomotives, "802" (page 828), will serve to show the immensity of these machines. The weight of this locomotive is 684,000 pounds, and the tractive effort which it can exert is 147,200 pounds The steam pressure is 215 pounds to the square inch. The engine proper is 64 feet long and the engine and tender combined are 97 feet long. The engine is so high that it will barely pass through existing tunnels and under existing bridges For this reason the smoke-pipe is reduced to a mere nozzle and the sand-boxes and other attachments are made of special shape so that they will not project above the top of the boiler. The whistle is horizontal.

The locomotive has passed through the stage of ornamentation. Polished brass bands once encircled the boiler, polished brass and bright work made the engine resplendent, while fancy brackets, scroll work and decorative painting gave what was supposed to be an elegant appearance to the machine The locomotive of today makes its appeal to the eye because it is obviously perfectly fitted to its work.

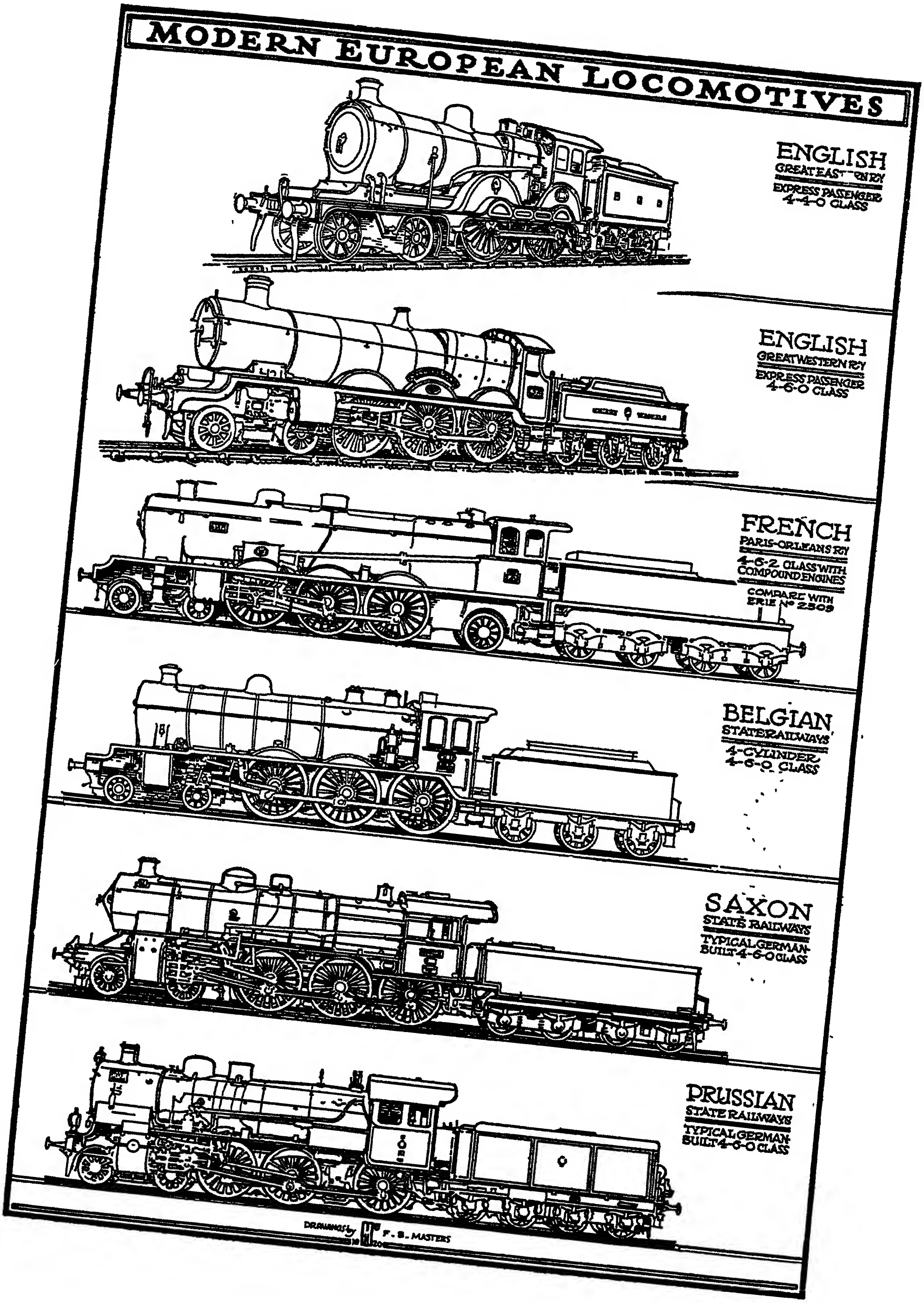
While the general characteristics of the locomotive are the same the world over, the exact arrangement of the essential parts varies with different countries. In America the cylinders are invariably placed on the outside of the frames on the side of the locomotive, both connecting rods and side-rods, therefore, being also on the outside of the machine. Until quite recently the eccentrics on the axle, and the links operated thereby for controlling the steam valves, were placed inside of the frames under the boiler. Of late the introduction of more modern valve gears, operated from the crank-pins, has brought all of this mechanism on the outside.

Differences in appearance and in construction of European locomotives from ours

Locomotives built in Great Britain for British railways frequently have the cylinders and valve gear placed under the boiler between the wheels, the connecting rods being coupled to cranks forged in the main body of the axles The side-rods for coupling the drivers are placed on the outside, as in American practice. It is claimed that this arrangement of parts makes the locomotive somewhat more steady in its action than when the cranks are on the outside On the other hand, the engine is more inaccessible and, because of the shorter connecting rods, the friction is somewhat greater. Both arrangements have their advocates. Of late, however, there appears to be a growing tendency in Great Britain and on the Continent to adopt the practice of placing the engine on the outside. Whatever may be the engineering advantages of inside construction, these are obviously largely offset by the ease with which repairs and adjustments can be made upon the engine that is coupled on the outside. This difference in arrangement of parts has resulted in a somewhat different style of finish between American and British-built engines, and the latter appear to be much simpler machines, though certainly, to our eyes, not so pleasing as the passenger locomotives of the Pacific and Mountain types, nor so impressive as the huge Mallet Compounds.

Great changes in the methods of locomotive construction since the early days

The great growth in size and power of the locomotive is paralleled, of course, in everything else pertaining to railroading. Steam pressures have risen till 200 pounds per square inch is common, rails weigh 120 pounds to the yard, coaches and freight cars have advanced in like ratio both in size and perfection. Naturally one looks for correspondingly great changes in the methods of locomotive construction. In a few years most of the small general machine shops without special equipment in which the first locomotives were built, had gone out of business.


MODERN EUROPEAN LOCOMOTIVES
ENGLISH
EXPRESS PASSENGER 4-4-0 CLASS
ENGLISH
GREAT WESTERN RY
EXPRESS PASSENGER 4-6-0 CLASS
FRENCH
PARIS-ORLEANS RY
4-6-2 CLASS WITH COMPOUND ENGINES
COMPARE WITH ERIE No 2509
BELGIAN
STATE RAILWAYS
4-CYLINDER 4-6-0 CLASS
SAXON
STATE RAILWAYS
TYPICAL GERMAN-BUILT 4-6-0 CLASS
PRUSSIAN
STATE RAILWAYS
TYPICAL GERMAN-BUILT 4-6-0 CLASS
DRAWINGS by F. S. MASTERS

But the Baldwin Works continued to grow and in time had competitors like the Brooks, Rogers, Dickson, Schenectady, and other plants once well known Today there are but two great American locomotive builders, who practically control the business in this country. These are the Baldwin Locomotive Works in Philadelphia and the American Locomotive Company, whose principal plant is in Schenectady. Up to 1921 the Baldwin plant alone had built 55,000 locomotives and its present capacity is 3500 per year The American Locomotive Company can produce about the same number. A few of the principal railroads have large shops where they make locomotives for their own use, but this output is, in comparison, negligible

Modern methods of production

Let us visit one of these great factories and see how their enormous output is obtained. Locomotive building, like many other modern industries, has become a highly specialized business, factories that build locomotives usually building nothing else. Furthermore, the work inside of these factories is specialized into departments, each devoted to one part of the work only. Thus there will be the engineering department where all the plans are made, each machine being fully worked out in detail on paper, and drawings sent to the several shops to form the basis of all construction. The shops will ordinarily include: pattern, foundry, forge, frame, boiler, machine (one or more), and erecting. In them a variety of trades will be found represented: machinists, pattern-makers, blacksmiths, boiler-makers, carpenters, foundry-men, electricians, etc.

A large engine like the "Matt H Shay," is produced practically as a single piece of work, and all detail parts are made specially for it. In such cases a special set of drawings would be made, special patterns for the castings and special connecting rods, etc., would be manufactured. Such an engine would possess individuality, and the parts would all be marked or numbered as they moved through the shops so as to be identified with this particular engine, just as in the early days of locomotive building.

The usual practice followed today in the case of small locomotives for contractor's service is to produce a number of machines of the same type and size at one time, though several types may also be under construction simultaneously. The cost per unit is, of course, much less when several of the same size can be built at once. Different types, or even different sizes of locomotives, often have individual parts that are exactly alike, and this allows certain departments to produce in advance such common parts in larger quantities, thus reducing production costs. In building such standard types, therefore, many parts are not made specially for the order in hand, but are drawn as required from the storeroom, which thus acts as a sort of reservoir between the erecting floor and the manufacturing departments, so that the latter may operate fairly continuously, while erection may be intermittent depending upon market demand.

Following the stages of a new machine

When a machine is to be made for the first time, wooden models, called "patterns," must first be prepared for all parts that are to be molded, whether of brass, cast-iron or steel. Pattern-making is, therefore, a refined sort of carpentry, and is conducted in the pattern shop, which usually has a fine equipment of wood-working machinery A considerable number of castings can be made from one pattern, and they are carefully stored in lofts and drawn out as needed. They are used in the foundry to make molds of sand which can be filled with molten iron, thus reproducing the pattern in metallic form The iron is melted in great furnaces called "cupolas," drawn off into iron ladles lined with heat-resisting clay, and carried by overhead traveling cranes to the molds or flasks, into which it is poured and allowed to cool and solidify In this manner are produced the cylinders and other castings. The side-rods, connecting rods and other parts that are made of wrought steel, are forged to approximate size in the forge shop under heavy power hammers and then machined to exact size in one of the machine shops.

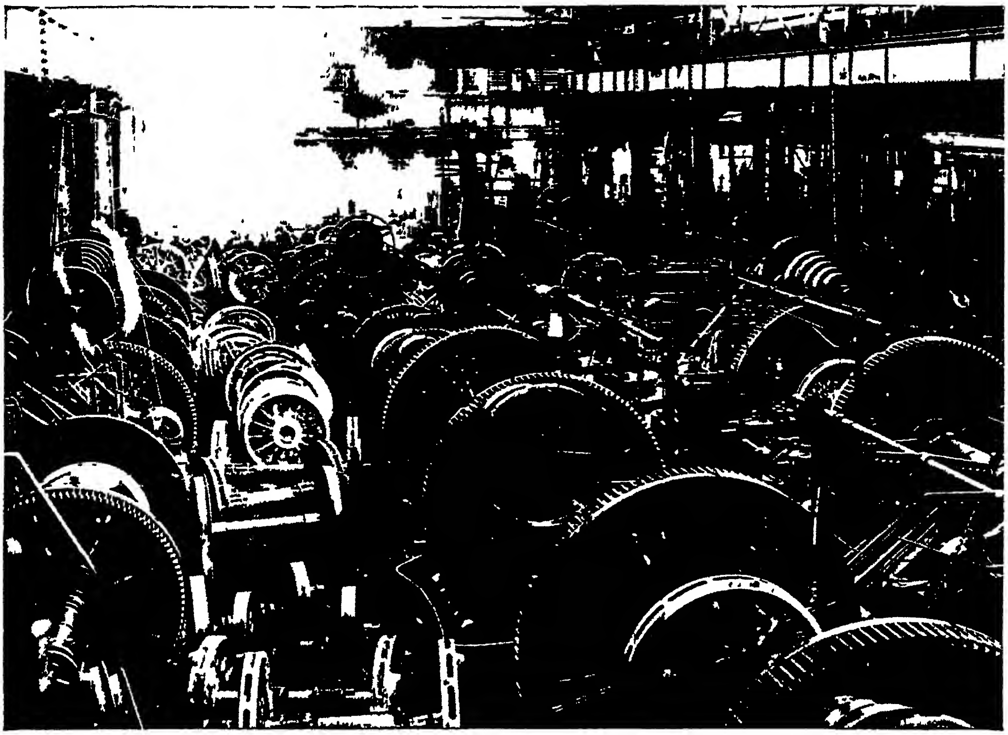
FOUNDRY OF THE AMERICAN LOCOMOTIVE CO. AT SCHENECTADY

Here the cylinders and other parts made of cast iron are molded in sand, and cast from molten metal

CYLINDER SHOP OF THE AMERICAN LOCOMOTIVE CO.

Here the cylinders are bored to a smooth surface, and other parts are machined, so that they can be secured to the frame and boiler.

ORDER COMING FROM APPARENT CHAOS



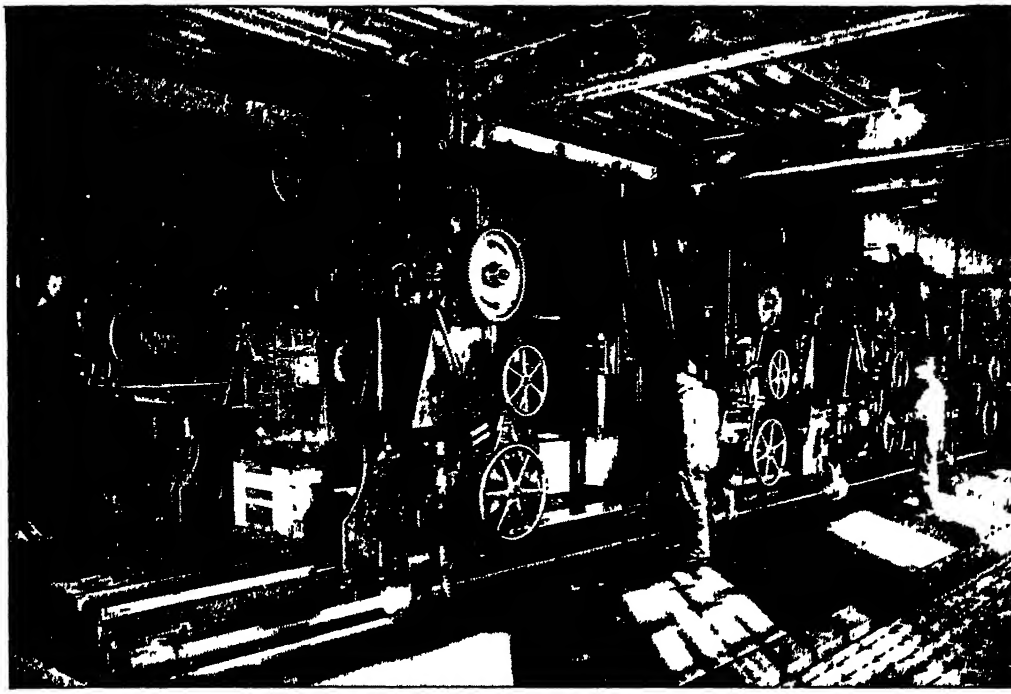
WHEEL LATHE SHOP OF THE BALDWIN LOCOMOTIVE WORKS AT PHILADELPHIA

This entire shop is devoted to the construction and machining of wheels and axles.

FRAME SHOP OF THE AMERICAN LOCOMOTIVE CO.

Here large frames, like those seen in the foreground, are machined.

IN THE BUILDING OF THE IRON HORSE



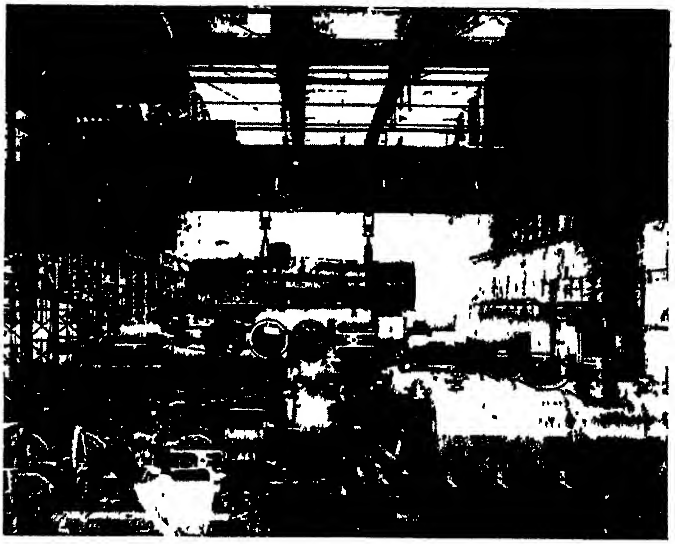
IN THE FRAME SHOP OF THE BALDWIN LOCOMOTIVE WORKS

This glimpse shows a large special machine which finishes the surfaces of several frames at the same time and works simultaneously upon several places

THE ERECTING FLOOR OF THE BALDWIN LOCOMOTIVE WORKS AT EDDYSTONE, PA.

This photograph shows the modern "progressive" method of erecting large locomotives.

One of the most interesting sights in a locomotive works is the boiler shop Here the sheets of steel that go to make up the cylindrical part of the boiler, and which may be seven-eighths of an inch in thickness, are rolled into proper form by heavy power-driven rolls as easily as a tinsmith rolls up a tin can The irregular shaped plates around the fire-box must have flanges turned around their edges, to secure them together and to the main boiler shell. This is done by powerful hydraulic presses, the edges of the plates being first heated red-hot so as not to break in the process. All the parts of the boiler must be held together by rivets spaced a few inches apart and the holes for these are carefully drilled so that those in mating sheets match accurately. The hot rivets, which may be as large as an inch in diameter, are "driven" in by hydraulic riveting machines which squeeze them into place as one squeezes a piece of putty. When the boiler has been completed it is tested under hydraulic pressure considerably higher than that under which it is to operate.



FROM ERECTING TO TESTING FLOOR

Transporting a locomotive from the erecting to the testing floor by means of a giant traveling crane, at the Philadelphia plant of the Baldwin Locomotive Works

The frames are machined in a shop specially fitted for that purpose. In machining the edges, several frames are piled one on top of the other and placed under a large machine, shown among the accompanying illustrations, which operates several cutting tools simultaneously, and insures that they are exact duplicates. In another machine shop the wheels and axles are fitted to each other and the outside of the wheels are finished to size. Another shop is devoted entirely to boring and the other machining connected with the engine cylinders, and to boring the valve chests. Still another shop will be found machining the connecting-rods, side-rods and similar parts, while other departments specialize on the production of the valve gear and controlling mechanisms

Finally each piece is inspected as to quality of finish and dimensions, so that the several parts will require a minimum of hand fitting, and the product of all the shops is carried to the erecting floor where the locomotive is assembled. The assembly or erecting floor is by far the most interesting department of the works. It is usually fitted with short sections of standard gauge track, laid transversely to the length of the shop, upon which the wheels can be placed as a foundation. When the frames are in place the boiler and engine are put in position and the connecting parts coupled up. When fully assembled, the locomotive is picked up bodily by a great overhead traveling crane and carried to the testing floor, which may be at one end of the same shop. Here the engine is tested by raising the locomotive up so that the drivers do not touch the track when the engine is running; sometimes an actual road test may be given. When the engine is found to work satisfactorily, the boiler is covered with non-conducting material to retain the heat, and this in turn with a sheet iron jacket. The finishing touches in the way of painting, striping and lettering are then applied.

At the erecting shop of the Baldwin Locomotive Works at Eddystone, Pa., special provision has been made for the erection of very large engines, like the Mallet Compounds, where the use of the traveling cranes is not attempted. Here the foundation tracks are laid longitudinally with reference to the shop and the locomotive is moved along upon the rails from department to department, arriving in its finished state at the end of the floor.

Locomotives are usually shipped to points in the United States upon their own wheels, being hauled "dead," as it is termed, like an ordinary freight car. In shipping to foreign countries it is usually necessary to "knock down" and box all removable parts During the war, however, the English army shipped many complete locomotives across the Channel in ferry boats specially fitted for this service, and a considerable number were shipped from this country completely assembled, by using ore boats, the hatches of which were large enough to permit the locomotive to be lowered intact into the hold. This, however, must be considered as exceptional and a practice not likely to be continued in peace times.

The preceding pages have had reference only to steam locomotives, operated by burning coal, oil or wood, directly. Of late years small locomotives driven by gas engines have come into common use for passenger service on short runs and as feeders to main lines They have so far offered no serious competition to steam locomotives There is, however, serious agitation of the problem of electrifying railroads handling heavy freight and passenger service, and some important and interesting projects of this character have been completed both in the United States and abroad The reader will find in the chapter on Ocean to Ocean Railways an account of the large electric locomotives used on the Chicago, Milwaukee & St. Paul Railroad over the Rocky Mountains, and the visitor to New York may see those that draw all trains that enter or depart from the Grand Central Station. Without doubt, where there is cheap power from waterfalls to be had, as in the first case, or where local conditions demand it, like the nuisance from city tunnel smoke in the second, the future will see the electric pressing the steam locomotive hard for public favor. Electric locomotives are used on many of the newer mountain railways, often in connection with rack and pinion. Several types are shown in the chapter on Mountain and Aërial Railways. They are especially effective where the grades are too steep to be negotiated by the ordinary traction locomotive. But probably it will be many years before the latter will lose its proud title of "King of the Rails."

MALLET COMPOUND LOCOMOTIVE

This is one of the large engines which draw the trains of the Union Pacific over the Sierra Nevada Mountains These great machines are 91 feet long and weigh 300 tons Each locomotive has two complete sets of cylinders each operating six driving-wheels The locomotive is so long that the engineer's cab has to be at the front end in order to have him see the roadbed ahead!

WOMAN, NO LONGER THE BURDEN-BEARER, BUILDS UP THE COMFORT OF THE HOME

There can be little doubt that woman founded the home ; there can be no doubt at all that in the early days woman was the burden-bearer of mankind. Over the greater part of the world the physical subjection of the mothers of the race has passed away, and woman has become the home-maker, the builder up and maintainer of the comforts of family life. This picture, called "The Laundress," painted by Alice Havers, hangs in the Walker Art Gallery, Liverpool.

THE TRIUMPH OF WOMAN

How the Women of Primitive Days Built the First Homes, Domesticated Man, and Gave Birth to Agriculture, Industry and the Arts

WOMAN AS THE MOTHER OF CIVILIZATION

ONCE it was commonly thought that the brain of man was much larger than that of woman. It has now been found, however, that, in proportion to the size of her body, she has a larger brain. Woman's brain-weight is to man's as 90 is to 100; but then woman's body-weight is to man's as only 83 is to 100. Professor L. Manouvrier, the French anthropologist, goes further than this, and estimates that the active organic mass of woman's body is to that of man's as, at most, 70 to 100.

She is also much less hairy and more delicately built. In short, she is "a child of a larger growth," and she can congratulate herself on this fact. Her superiority in comparative brain-mass, however, implies no intellectual superiority, but is merely a characteristic of short people and children. On the other hand, there seems to be no reason for the belief that women are naturally slightly less intelligent than men. Many of the differences between the adult sexes of civilized communities are due to differences in education. By education we mean not only mental training, but mainly muscular education, bearing on the individual development of the nervous organization.

Man undoubtedly possesses some natural advantages over woman — he is stronger in body, for instance, while the woman is stronger in constitution. This fact has determined the natural division of labor between the sexes. From the beginning man has been the fighting animal, and woman the domesticating force. Woman has made the home, and man has guarded it. Man has invented the weapons of human supremacy over the wild beast, woman has discovered the means of turning plants into food. Man has generally undertaken the work requiring great effort exerted suddenly and for a short space of time, woman has done most of the hard drudgery of existence

In appearance, a woman of a savage type is the most oppressed creature on the earth. She can still be seen, among the lower hunters, trudging along, carrying a hundred pounds of household utensils, with often her last-born child slung behind her back or straddling over her shoulders. She will walk like this for twenty miles a day. In front of her strides her husband with nothing in his hands except some weapon of defense. "It does look bad," says Bishop Selwyn, "but it is really an excellent division of labor. A savage woman can carry a very heavy burden, but she cannot defend herself as well as a man can."

With a little alteration, this picture of modern savage life can be made to represent the primitive state of the relation of the sexes. The woman bore all the burden, and man walked in front of her with his club or his stone ax, ready to defend his mate and his young from beast of prey or human rival. When human warfare began, more routine work fell on the woman, and more risk and danger on the man. Probably for hundreds of thousands of years the inventive genius of the human male was spent chiefly in devising instruments of destruction. He threw away his wooden club, and began to shape rude axes and weapons of bone and flint; he became cunning in making traps, and wise in the ways of both the animals he feared and the animals he hunted for food.

Man the hunter and woman the founder of the home

First in hunting, and then in war, he learned to act in concert with bands of his fellow-men, and laid the foundations for those social cooperations on a large scale out of which grew the clan, the tribe, and the nation. His field of action thus became larger than the woman's, and in favorable circumstances he seems to have developed somewhat larger powers of mind. These powers, however, he did not apply directly to the development of home life.

It was left to woman, in all probability to originate the industries of peace Perhaps man found the cave, but it was woman who built the house. Moreover, there are grounds for believing that the primitive house came into use before the cave. The lowest of the lower hunters has no fixed place of abode. He cannot stay long in one place, as he soon exhausts the game and other natural resources. Even a hunter of the higher type, like the American Indian, wanted about ten square miles for himself; he possessed this in New York before the white settler drove him away. As a rule, a hundred farmers can live on the area a single hunter requires.

The wandering woman who carries her house about the world

At the present day, Australian natives sometimes travel twenty miles between sunrise and sunset. The woman carries all the furniture. Here is a list of it, made by Sir George Grey: A flat stone to pound roots with, earth to mix with the roots, quartz to make knives and spears of, stones for fashioning into axes, cakes of gum used in mending weapons and sticking down the bindings that kept stone instruments inclosed in their wooden handles, kangaroo sinews for thread, needles made of the small bones of the kangaroo, opossum hair for waistbelts, shavings of kangaroo skin to polish spears, some grease, and stone knives and axes. In addition to all these things, the savage woman carries a digging-stick, with which she digs up roots. It is also her building implement.

When the family arrives at a good place to camp, the woman digs eight holes with her digging-stick Into these holes she puts eight poles. The upper ends of the poles slant towards each other and meet in such a way that they do not require to be tied together, thanks to the art with which the woman builds her house. Through the poles the woman laces smaller sticks, and over them she places a layer of grass and leaves or pieces of bark. Thus is formed a small rainproof shelter, serving fairly well as a temporary dwelling-place, but representing scarcely any advance on a bird's nest. The women of the Bushman race, which is somewhat higher in culture than the lowest of Australian natives, make a portable shelter of mats. The Indian woman also carries her wigwam with her when she goes on a march. It is a valuable thing, made out of the hides of animals.

Everything thus goes to show that the female of the earliest wandering races was the original home-builder. Shelter was more important to her than it was to the man, for she had a frail child to protect from the inclemencies of the weather.

The invention of clothes in a Europe that grew colder and colder

Perhaps it was also for the sake of the child that woman invented clothes. Among the rude stone axes of the earliest races in Europe are found the skin-scrapers used by their women. These skin-scrapers are to be found in considerable number among the most ancient of prehistoric remains and they were our first tangible evidence of the activities of very early women. But now it seems clear that our remotest ancestors were clothed by their wives and daughters. It was growing cold in Europe in those far distant days, and it is probable that the women began by making dresses for themselves.

This stage of culture was recently found among the natives of Tasmania. The men went naked, but the women wore a loose covering of skins. Man, the hunter, was certainly the last to take to clothing, for it impeded him in his craft, until he became well used to it.

The first tailor and the first weaver of the early world

With few exceptions, savage races throughout the world still throw on women the task of working up the hides of beasts into clothes, tent and canoe coverings.

There is some doubt whether woman invented sewing; at least, Professor William I. Thomas is inclined to give man the credit for discovering the uses of the bone needle and the tough tendons from the back or leg of deer and other mammals. It is supposed that these threads of sinew were first used by the hunter in setting snares, and then adapted by him for the purpose of sewing skins together. However this may be, the savage woman now is usually the tailor as well as the skin-dresser of her tribe; she is also the shoemaker and the tentmaker. It is true that the males of the North American Indians make their war-dresses themselves.

Again, the young Zulu has, by custom, to make for his bride a petticoat reaching from her bosom to her knees; he scrapes and rubs the hide until it is as soft and as smooth as a fine cloth. But this, too, seems to be a rite. On the whole, all the evidence available goes to show that woman invented clothing.

Woman was also the first weaver. She began with reeds and green, flexible twigs. Being the bearer of burdens and the fetcher of water, she wanted something in which to carry her belongings. She had already practised a rude kind of basketry in weaving twigs into a shelter against the rain.

The far-off, primitive beginning of the art of the potter

The very lowest of known savages can at least weave twigs together in a rough fashion. Above them are the tribes which make rough hampers — the women, of course, doing the work. Then baskets of all materials appear — wood, bark, grass, skins, and roots. The best example of this kind of woman's work is a basket of roots or grass, woven with a two-ply twine, in which the twines are driven so close together as to make the vessel water-tight. Here we come to the origin of pottery.

These woven vessels are often as water-tight as goatskins or stoneware, and they are used for cooking Water and food are placed in them, and stones are heated in a fire close by and dropped into the water. When the baskets showed signs of wear they were plastered with wet clay, and when this dried hard it was possible to put the vessel on the fire. The remains of the most primitive pottery are distinguished by marks of twine-woven basketry, showing that the pot was made by plastering a basket with clay and then burning it

This, however, is a very laborious and roundabout process; and the next advance that woman made was to weave a pot. She rolled a piece of clay into a long ribbon, and, taking a low basket bowl, built up inside it a series of clay rings. On reaching the level of the bowl, she still kept twining the ribbon of clay round and round until she had formed a vessel three or four times higher than the bowl. Each coil of clay was firmly pressed against the coil beneath, so that the vessel became waterproof. It was then set to dry, and rubbed down with a smooth stone.

The surprising things that came out of the primitive woman's basket

The next step that woman took can be traced among the women of New Caledonia. Instead of twining a ribbon of clay inside a basket bowl, they place the wet clay in an old clay bowl which they keep turning rapidly as they mold the clay with their fingers. Here we find the most primitive form of the potter's wheel; so we must acknowledge that woman is the entire inventor of one of the most useful of domestic arts. That primitive basket of hers was, indeed, like the basket of the modern conjurer. Out of it came a number of surprising things. In making her little house of boughs and twigs she used a stick to interlace the branches together. In the finer work of basketry the stick was refined into a sharp little wooden awl. Then came the finer bone awl, which, Professor Otis Tufton Mason, of the U. S. National Museum, says, is found in almost all the graves of primitive woman.

It was woman, no doubt, who first wove a shelter of interlacing twigs to shield her child from storm and cold; then, improving in the art of plaiting, she made a basket; and by lining this with clay and burning it over a fire she discovered pottery.

Primitive woman, we may safely assume, collected wild grass seeds, nuts, and acorns; and, while her husband was busy hunting, she invented the arts of agriculture, which domesticated man, attached him closely to the soil, and made civilization possible.

Surely it was she who first thought of boring a hole in the tool that she alone used and used constantly. So we must conclude, against Professor Thomas, that out of the basket of the woman came the needle. Then followed rope and cloth.

Primitive cloth was made out of the fiber of the bark and leaf of various trees For instance, filaments as fine as silk can be obtained by heckling the fibrous bark of the American cedar with a bone knife. This was the method adopted by the Indian women around Fraser River in British Columbia; while in the warmer lands of South America, and in Africa and Polynesia, cocoa bark, palm-leaf fiber, and pita fiber were used. The thread was first spun by fastening the strands to a stone, which was twirled round till the yarn was sufficiently twisted. The yarn was then wound upon the stone, and the process was repeated over and over. Thus the idea of a spindle was discovered, and the spindle itself, with its spindle whorl, followed.

The weaving-loom that came out of the magic basket

And then, out of the magic basket, woman, the inventor of all the domestic arts, brought forth the weaving-loom. It first consisted of two rows of sticks, fixed opposite to each other in the ground. The warp was fastened to these sticks, and the threads of the woof were passed through with the hand, and pressed back by a rude wooden comb. The simplest form of hand-loom is to be seen in use among the savage women of British Guiana. They use it for making their aprons. The frame consists of two rods, one flexible and bent in a semi-circle, the other straight and having its ends tied to the ends of the bent rod. Thus it formed a simple frame, shaped like the letter D. The warp threads pass from one rod to the other, and the woof is woven into them by means of a slender stick on which the yarn is wound. Long before the white man came to America, hemp and cotton were used by tribes in the lowest stage of culture. Even the cannibal Carib woman of the West Indies had a primitive cotton plantation.

Agriculture, the most important of all the achievements of woman

This brings us to the most important of all the achievements of woman. There is little or no doubt that she discovered agriculture, and thus domesticated man and founded civilization. Neither the lower nor the higher hunters are able to keep themselves and their families on the spoils of the chase. Primitive woman is the chief food-bringer. In her exploitation of her peculiar kingdom — the vegetable world — woman first appears in the act of taking from the hands of nature those fruits and other parts of the plant which are ready to be eaten. On her next journey she ventures a step further. With digging-stick and carrying basket she goes out in search of roots which have to be roasted or boiled with hot stones to make them human food. Then, on her third journey — she is still taking it in the wilder parts of Australia — she gathers the seed of grasses. In our list of the furniture of the Australian woman we omitted a curious stone about eighteen inches square and several inches thick. It seems a far stretch from one of our huge, steam-driven flour mills to this square of stone which the black-fellow's wife carries with her in all her long wanderings, but all the steps in the development from this stone to the modern mill can easily be traced.

Having collected the seeding grass, the woman digs a hole twelve inches deep, and puts the bundle in it and stamps on the grass until the seed has fallen out and worked to the bottom. She then clears the hole and collects the seed, and winnows it in a large bowl, using her breath if no wind is blowing. After this the seed is laboriously ground on the square stone, and moistened and scraped into the bowl, and eaten either cooked or raw.

This is the nearest that the natives of Australia have approached to the arts of agriculture. The almost extinct Bushmen were scarcely more advanced. Their women collected the seeds of wild grasses, which they pounded in mortars hollowed out of the rock.

The prehistoric women of Europe who ground the corn

The Bushmen, of course, lived in a land where game was always very abundant; and it seems likely that their women failed, for want of the pressure of hunger, to take the great step in cultivating the plants that grew around them. Stones with a curious resemblance to mullers have been found among the oldest prehistoric remains in Great Britain. A muller is a flat stone which the grinder takes in her hand when she is pounding seeds or nuts or acorns on another flat stone, or in the hollow of a rock, or a portable mortar, to make a coarse flour

So it looks as though the prehistoric woman of Europe was on the same level as her modern sister in California — who, a few years ago, harvested the acorn, the pine nut, and the seeds of sand grass. With the same free movement of the body with which a modern washerwoman washes clothes, her savage sister rubs her muller up and down and sideways upon the nether slab. The work is done in a kneeling position, and it is very hard. Hollowing out the nether stone and converting it into a mortar make the task more easy; and from the mortar is developed the hand-mill, worked by two women.

In northern California, where, as in ancient Britain, acorns are ground for food, we find the most primitive form of existing granary. It consists of a wicker hamper, holding about a bushel, and it is set up, full of acorns, in the huts. In southern California the wicker granaries are very large. Roughly thatched, and lifted by wooden pillars above the ground, they show quite as much art and foresight as the ricks our farmers build.

There is ample proof that among the three typical divisions of mankind still in savagery — the American Indian, the negroid races, and the Malayo-Polynesians — the women are the builders and owners of the first caches, granaries, and storehouses. There is every reason to believe that the same state of things obtained among the now higher peoples when they were at a low stage of culture.

The work of women among savage races in these days

And if we admit that woman throughout the world was the founder and owner of the primitive granary, we must allow that she was the inventor of agriculture. For the granary is the last step toward the tilled and sown field. In America woman took a grass, which is still to be found growing wild, and cultivated it into Indian corn. In Africa she grew millet and mealies, as she does now. In Asia she transformed the wild rice, and probably in the fields of Asia and Europe she cultivated wheat. The general fact that woman still remains, among practically all existing savage races, the cultivator and the harvester is additional evidence that she may have been the original founder of the arts of agriculture.

Women domesticated man, the cat, and the plant; man tamed the dog, reindeer, cattle, sheep, and various beasts of burden. Both of these achievements made for a settled home and an abundant food supply for the entire family.

The woman's step that is the most important advance made by humanity

In some parts of the world, where — until the advent of the white man — cattle-keeping on a large scale was unknown, it was given entirely to woman to strike down the path leading to civilization. In several regions of the Old World, however, man seems to have taken to keeping and breeding cattle before woman engaged in farming in a large way. Nevertheless, the primitive stock-breeder remains a semi-nomad, wandering from summer pasturages to winter pasturages. Cattle raids and tribal quarrels kept him continually at war with his neighbors. As a rule, it is not until a people settles down to agriculture or industry that it falls into a way of life sufficiently settled for a civilization to grow out of it. To woman, therefore, must be attributed the most important advance made by humanity.

We must remember that her life was fairly easy in the pastoral days, when she made her last and greatest discovery.

Man not only guarded and largely fed her and her children, but he took over a great deal of the routine work. He drove the herds afield and shielded them from beasts of prey and human foes. Often he was compelled to fight as hard as he did in the hunting age, and he had still to conquer the wild beasts that ravaged his herds and flocks. He was more continually busy than when he lived on the game he trapped and slew, but his new way of life relieved the woman of some of her heaviest burdens

These burdens, it must clearly be understood, were not imposed upon her by man. They fell on her shoulders in the natural course of things

The division of labor which established economic equality between the sexes

We must not, it has justly been said, abuse the poor savage man who lies idle in the sun for days after his return from hunting, while his heavily laden wife toils and moils without complaint For when we consider the extreme bursts of exertion required of him in his struggle for food and life with nature and his fellows, we see that he must use every opportunity of repose to recruit and eke out his brief and hazardous existence. On his strength directly depends the welfare of his wife and offspring.

From the beginning of time until man invented the steam engine, there has been, all things considered, a fairly equal division of labor between the sexes. Man has done most of the work requiring power used swiftly and violently; he probably discovered the use of fire, leaving woman, of course, to guard it and employ it for cooking. He built the boat which enabled the human race, probably in the Stone Age, to spread over the whole habitable world; and he solved the problem of a constant meat and milk supply by domesticating many of the animals he once hunted. He founded religion and philosophy and law, and many of the larger arts of life. Woman, as we have seen, discovered the domestic and agricultural arts; and she probably found out the medicinal value of herbs.

By working side by side, yet in different directions, man and woman arrived at a condition of economic equality. Woman became an agriculturist, and man a cattle-breeder. This state of things is finely described in the Book of Proverbs.

This was a happy stage in the history of mankind, and on it the ancient poets built their beautiful fable of the Golden Age of the past. We have already traced in previous chapters on the Family and Marriage the effect on woman herself of her increased value from the economic point of view. Her position as a daughter, wife, and mother became more stable; desertion and divorce grew rare; the children received more attention, and the general span of human life was lengthened.

This was also the time when women generally began to count politically. Unfortunately, the records of most of the civilized nations do not go back very far. We know very little about the Egyptians of the first dynasty, and much less about the Cretans, who seem to share with them the honor of being the earliest of all the races of mankind to arrive at civilization.

The time when women began to count politically

This happened probably six thousand years ago. Two thousand years later, we find in the laws of the Babylonian king Khammurabi the first clear evidence of the position won by woman in the early agricultural states. Her freedom and dignity were very remarkable. Her husband brought her a dowry, and when he died she became the head of the family. In case of divorce, the innocent wife was given the dower and the custody of the children, and her husband had to pay her an annuity.

Slandering a married woman was as grave a crime as slandering a sacred vestal, and the slanderer was branded, and made, it would seem, a slave for life. In Egypt, moreover, inheritance obtained through the female line, and succession through the mother. As in England in the Elizabethan and Victorian ages, the queens reigned in their own right — like Nitocris of the eighth dynasty, Scemiophrus of the twelfth, and the famous Queen Hatshepsut.

The equality of woman with man seems to have extended at times even to the priesthood, for we find woman as priestesses in temples dedicated to female divinities. Significant also is the rank occupied by goddesses in the pantheon of the two great agricultural nations of ancient times. In Babylonia, Istar was the mother of all the gods; and down to the days when the Christian Church was founded, the Egyptian Isis, wife of Osiris, was practically supreme among the Egyptian deities. In Assyria, Astarte was the highest goddess; in ancient Arabia the goddess had more power than the god, and so she seems also to have had in Moab and other lands.

The wife of a peasant to whom Israel turned for advice

Still more significant, in the circumstances, are the power, authority, and place which Deborah won among the monotheistic and republican Jews in the age of the Judges. Perhaps not more than a hundred years after the death of Joshua, a woman won the rule over the fierce, warlike tribes from the desert, who still had more of the raiding habits of the Bedouin than the love of peace and settled life of the farmer. Their religion was warlike and wholly masculine; there seemed to be little place in it for women; yet in the time of great national peril it was to the wife of an obscure husbandman that Israel turned for guidance and inspiration.

Energy, will, mother-wit, endurance and sagacity seem still to be found more in women of the peasant class than in those in other walks of life. In managing ability, she is often superior to her husband.

On the other hand, it is equally patent that woman soon lost much of her monopoly in agriculture. When she had tied man down to the soil and domesticated him, he brought to bear on their common task of tilling the land the powers of mind and body developed in the hardest and most strenuous school of life. Trained to concerted action in hunting and in war, he had greater and better organizing force than woman, who still remains individualistic in thought and feeling in matters not directly related to the home circle.

Man carries out the work in the field that woman discovered

Man transferred to labor the organizing capacity he had developed in more violent ways of life, and when he came to settle down as an agriculturist he acted with his fellows on a large scale — clearing the jungle, preparing the land, diverting water-courses, and building roads.

Man also brought with him to his new industrial occupations a superior skill in fashioning instruments. For a million years, perhaps, his life had been a life of strains — a continual fight against death in all forms, in all attitudes — and this had stimulated his powers of invention. So when he took at last to making and handling tools, he was greatly helped by his practice in making and handling weapons. Woman first thought of thrusting a stick in the earth and dropping the seed in, and awaiting a meager harvest, but when man gave his attention to the matter he gradually worked out a remarkable combination of all the materials and powers within his reach. The great rivers by which he settled he split up into little, irrigating, fertilizing rivulets of water. The bucket that woman had invented for carrying purposes he placed on a wooden structure beside the stream, and turned it into a sort of pump for watering his far-off fields. The woman's hoe he transformed into a plow, and to it he harnessed the animals he had tamed in his semi-nomadic days.

So he went on improving in every direction on the primitive inventions of women: and in the end woman retired from the field that she had discovered, and devoted herself mainly to developing industries of a purely domestic sort. This new division of labor had in some cases a bad effect on the position of woman. In China, in India, and in ancient Greece she was sometimes driven completely indoors, and the door was shut upon her. Woman, the founder and discoverer of the arts that make for happiness, was put under subjection. This was undoubtedly an act of tyranny, and the children at last suffered for the indignities done to the mothers of the race.

PIERRE MARCELLIN BERTHELOT, ONE OF THE MASTER SCIENTIFIC MINDS OF MODERN FRANCE

CHEMISTS AND PHYSICISTS

ANDRÉ MARIE AMPÈRE

From Whom is Named a Unit of Electrical Measurement

ANDRÉ MARIE AMPÈRE was born at Polémieux near Lyons, France, in 1775. From his earliest youth the study of figures had a peculiar fascination for him, and his father, discovering his bent, allowed him free scope and ceased to urge upon him the study of the ancient languages. Ampère, however, was catholic in his tastes and after a brief respite returned to his Latin, that he might read the works of the great Swiss mathematician Euler and Bernouilli. He was accustomed, later in life, to say that he knew as much about mathematics when he was eighteen as he ever knew, but his reading embraced the whole round of knowledge—history, travels and science There was perfect sympathy between father and son, and when in 1793 the former was guillotined, the tragedy produced so great an effect upon the son's mind that for a year he did no work and remained sunk in melancholy. A new study aroused him; some letters on botany fell into his hands, and he sought solace in the study of nature and the Latin poets. Moreover, his mind was further distracted from his grief, as at this time he fell in love with a young girl, Julie Carron of Lyons, and in 1799 the two were happily married. After 1796 Ampère earned his living as a private tutor of mathematics in Lyons.

In 1801 he moved to Bourg to become professor of physics and chemistry in the Central School of the department of Ain, leaving his ailing wife and infant son at Lyons. She died in 1804 and he never recovered from the blow. In that same year he was appointed professor of mathematics of the lycée of Lyons, and a treatise, *Considérations sur la théorie mathématique du jeu*, written at the time, gained for him a position in the Polytechnic School in Paris, where he was made professor of mathematics in 1809. In 1814 he was elected a member of the Academy of Sciences and in 1824 was appointed professor of experimental physics in the College of France. He died at Marseilles on the 10th of June, 1836.

As the "New International Encyclopedia" says:

"Science is largely indebted to Ampère, especially for his electrodynamic theory and his original views of the identity of electricity and magnetism. He was the inventor of the astatic needle which made possible the modern astatic galvanometer, and he was the first to show that two parallel conductors carrying currents traveling in the same direction attract each other, while if traveling in opposite directions they repel each other. He also formulated the theory that there were currents of electricity circulating in the earth in the direction of its diurnal revolution which attracted the magnetic needle."

The unit of strength used in measuring the intensity of an electrical current has been named "ampere" after this distinguished physicist By intensity of current is meant the quantity of electricity which passes any cross-section of the wire or conductor in one second of time; the instrument used to determine such intensity is called a "silver voltameter"

In addition to his researches and studies Ampère left a number of scientific memoirs and papers, one of the most notable being his *Essai sur la philosophie des sciences* Arago delivered a eulogy on Ampère shortly after the latter's death, which will be found translated in the Report of the Smithsonian Institution for 1872. It contains an account of his life.

SVANTE AUGUST ARRHENIUS
Great Swedish Physical Chemist

SVANTE ARRHENIUS was born at Wijk, near Upsala, Sweden, on the 19th of February, 1859, and was a student at the university there and at Stockholm from 1876 to 1884. He studied abroad for several years, visiting the Riga Polytechnic and the universities of Wurzburg, Graz, Amsterdam, and Leipzig, carrying on original investigations in collaboration with some of the leading European chemists and physicists of the day. In 1891 he was made lecturer in physics at Stockholm, and in 1895 full professor. He lectured at the University of California in 1905. Arrhenius is a member of a great number of learned societies in America and Europe, and has received honorary degrees from the principal universities as well as the Davy (1902) and Faraday (1914) medals and the Nobel prize for achievements in chemistry (1903).

One of the most important among recent contributions to science is due to his researches when he established (1884–1887) the theory of electrolytic dissociation by which chemical processes are explained as dependent on the electric conductivity of the reacting solutions — that is, a substance whose aqueous solution is capable of conducting electricity is broken up in solution into parts charged, some with positive others with negative electricity For instance, ordinary brine contains, on this theory, electropositive "ions" of the metal sodium, and, separated from them, electronegative ions of chlorine. This theory furnishes a reasonable explanation of many otherwise inexplicable chemical phenomena and correlates facts which in no other way can be connected.

ALEXANDER DALLAS BACHE
Who Established the First Magnetic Observatory Here

ALEXANDER DALLAS BACHE was born in Philadelphia, on the 19th of July, 1806 His grandfather was postmaster general of the United States from 1776 to 1782; his grandmother was Sarah Franklin, the only child of Benjamin Franklin, and herself eminent as one of the heroines of the War of Independence At the age of fifteen, he was appointed a cadet at West Point. Though the youngest boy in the Academy he was graduated in 1825 at the head of his class. During the first year after graduation, he remained at the National Military Academy as assistant professor, and in the summer of 1826 was assigned to engineering duty under Colonel Totten, at Newport, R. I. In 1828 he was appointed to the chair of natural philosophy and chemistry in the University of Pennsylvania.

This marks the beginning of Bache's career; for seven years he retained this position, teaching and seeking to enlarge the bounds of science by discoveries of his own. He became a member of the Franklin Institute, a society then newly established for the promotion of the mechanical arts, and of the Philosophical Society, and their transactions contain some twenty-five contributions from him within this period, all of them recording the results of original scientific research.

In an observatory erected in the yard of his dwelling he determined with accuracy, for the first time in this country, the periods of the daily variation of the magnetic needle, and by another series of observations the connection of the fitful variations of the direction of the magnetic force with the appearance of the aurora borealis.

Terrestrial magnetism was always with him a favorite subject, to which he continued to make valuable contributions at intervals during his whole life. The phenomena of heat also engaged his attention, and he was the first to show that the radiation and consequent absorption of dark heat is not affected by color.

In 1836 Bache was elected president of the trustees of Girard College who, preparatory to organizing the institution, sent him to Europe to study systems of education, discipline and equipment abroad. He remained two years and on his return embodied the results of his researches in a report which has accomplished much in the betterment of education here. There was delay in the organization of the college, and Bache offered his services gratuitously to the city of Philadelphia. The result of this offer was the establishment of the best system of combined free education which had at that time been adopted in America. In 1842 he returned to his former chair of natural philosophy and chemistry in the University of Pennsylvania, and in 1843 was appointed to the superintendence of the Coast Survey and Office of Weights and Measures

The Coast Survey had been recommended to Congress by President Jefferson in 1807, but not until 1817 was the work actually begun under the superintendence of Hassler, an eminent Swiss engineer. So limited had been the appropriations and so frequent the changes in government that when Bache took charge it was still in its early stages. The survey so far accomplished extended only from New York Harbor to Point Judith, on the east, and southward to Cape Henlopen. Bache greatly enlarged the field of labor, dividing the whole coast line into sections, and organizing under separate parties the simultaneous survey of each. He began a series of observations of the Gulf Stream, the tides, winds, magnetism of the earth, and the fauna of the ocean bed. With an appreciation of the value of abstract science he kept in view and cherished the hope of solving the various problems relative to the physics of the globe; among these a new determination of the magnitude and form of the earth; the general theory of tides; the magnetic condition of the continent, and the improvement of the general map of the United States by determining its relation to the coast line, and the precise geographical position of the most important points in the interior.

In 1846 he was named one of the regents of the Smithsonian Institution, and continued in this office until his death. It was through his influence that the policy (which has given the institution its present renown) of supporting original research in different branches of science was adopted. During the Civil War he was vice-president of the United States Sanitary Commission. At the request of the governor of Pennsylvania he planned lines of defense for Philadelphia, and his advice and information were continually required in Washington in military and naval operations. His life under this confinement was shortened, and he died at Newport, on February 17, 1867, in the sixty-first year of his age

ANTOINE CÉSAR BECQUEREL

Improver of the Electric Battery

ANTOINE CÉSAR BECQUEREL, illustrious father of an illustrious family, was born March 8, 1788, at Châtillon-sur-Loing, in the department of Loiret, in the heart of France. He is one of the most famous of French students of chemistry and electricity; and his sons and grandsons and great-grandsons have nobly continued his work, and made the name of Becquerel a mark of intellectual aristocracy. It was an accident that turned the mind of the older Becquerel to the pursuit of knowledge. Brought up amid revolutions, invasions, and raids that carried the French flag in victory from end to end of Europe, the boy was dazzled by the glory of a military career under Napoleon. In 1806 he entered the Polytechnic School at Paris, and so distinguished himself that at the end of two years various careers were open to him. He chose the army, and went as sub-lieutenant to Metz to complete his engineering knowledge. The following year he started out for Spain as an officer of engineers in the army of General Suchet.

From 1810 to 1812 he worked with skill and energy at six great and terrible sieges, and was mentioned several times in the order of the day for his brilliant actions

The rigors of the campaign undermined his delicate constitution, and at the age of twenty-four, when he was made knight of the Legion of Honor, he was compelled to retire. The position of under-inspector of studies was especially created for him at the Polytechnic School in 1813. When France was invaded by the allies, he again went out into the firing line, but again, at the age of twenty-seven, his health entirely gave way, and he had to leave the army. For some time he hesitated in the choice of a new career before he took up electricity.

He had now found his proper field of work; and the five hundred works which he wrote during his long life were almost exclusively devoted to discoveries made by him in the new and obscure branch of physics. There is not a chapter in the history of electricity to which he has not contributed something of importance. To him we owe the theory of the electric battery. Volta discovered that when a positive and a negative metal, such as copper and zinc, are brought into contact, an electric current is produced. Becquerel showed that the production of electricity is not caused by the contact of the two metals, but by the chemical action between them. Then he went on to prove that the molecules of a metal work by friction, heat, chemical action or pressure in the development of electricity.

He greatly improved the electric battery, and enabled a constant current to be obtained from it. He showed how elements of various kinds could be obtained by means of an electric current, and he invented instruments of great precision for measuring electromagnetic forces.

Becquerel loved his family, and was the best and wisest of fathers. On the education of his two sons he spent the most loving care, and established the great Becquerel tradition, which is as strong at the present day as it was when his son, Alexandre Edmond Becquerel, succeeded him, on his death on January 18, 1878, as professor at the natural history museum.

ANTOINE HENRI BECQUEREL
Father of the New Alchemy

ANTOINE HENRI BECQUEREL, the son of Alexandre, and grandson of Antoine Becquerel, was born in Paris on December 15, 1852. He also held the family professorships, winning them, of course, entirely by personal genius, and he completely revolutionized the foundations of modern science To him is directly due the discovery of radium and the radioactivity of matter. So, indirectly, he is the father of the new alchemy, whereby elements that were long thought to be unchangeable are actually split up and transformed into different elements.

His father had spent his whole life in researches on light and electricity. The son developed these researches, and discovered that certain forms of matter emitted a mysterious radiance. It was Rontgen's discovery of the wonderful X-ray that excited Becquerel. He returned to his grandfather's early study of minerals; and after some experiments on uranium he found that this element at ordinary temperature gave forth an invisible ray (known in his honor as "Becquerel rays") that passed through thin plates of metal, and affected a photographic plate — a ray that in many respects was like the X-ray of Röntgen.

For his work on the problems of radioactivity he was, in 1903, awarded the Nobel prize for physics jointly with Curie, whom he had put on the track of radium. Like his father and grandfather he did important work on magnetism and polarized light, phosphorescence and the absorption of light in crystals.

He was a great engineer, and directed the bridge-building of France; he also taught in the Polytechnic School of Paris, in which he and his father and grandfather had studied as boys. His activities were so diverse and so great that he wore himself out in middle age, and died in Brittany on August 25, 1908. A fourth generation of the Becquerel family is continuing with distinction the scientific work in which their ancestors labored for a hundred years.

PIERRE EUGÈNE MARCELLIN BERTHELOT

Founder of Synthetic Chemistry

PIERRE MARCELLIN BERTHELOT, one of the master minds of France, was born in Paris on October 29, 1827. The son of a doctor, he distinguished himself as a boy by the variety of his studies, and, without passing through any school, he won, in 1854, his degree of doctor of science. Appointed to the humble position of manual assistant to a professor of chemistry at the College of France, he served him for nine years, but spent his leisure time in carrying out a series of remarkable experiments which enabled him to construct a new system of chemistry. No one at that time thought that man would ever be able to make in laboratories and factories the substances produced by living bodies.

So when Berthelot published, in 1860, his great work on "Organic Chemistry Founded on Synthesis," the effect he made on the general mind was staggering. But there was no disputing the conclusions of the French chemist. His experiments in building up the products of living things could be repeated and verified by any man who followed his methods. So the success of his system and his ideas was instantaneous. The professors of the College of France and the chemists of the Academy of Sciences demanded from the government the creation of a special chair of organic chemistry for Berthelot. This was done at last, in 1865, and for forty-two years Berthelot worked without interruption in a position of high authority.

In person he was a small, quiet man with a remarkably large head. Having, as he proudly claimed, shown there was no mystery remaining in the universe, and reduced the processes of life to a matter of chemical laws, he was at heart, naturally, one of the most melancholy of men. He was most intensely patriotic, and took a tremendously active part at the siege of Paris. He directed the making of cannon and the manufacture of gunpowder and dynamite, and planned the researches of one of his pupils that led to the invention of modern smokeless powders of high energy.

Out of this practical work Berthelot developed another branch of science in which he again did some masterly pioneering labors. Taking up the chemistry of heat, he undertook a series of dangerous and delicate experiments with the most powerful explosives. He showed that an explosive energy proceeded in waves, and he measured the length of these undulations of terrific force. Out of the science of explosions that he constructed comes much of the practical application of the highest energies to industrial purposes. Berthelot would have been a very rich man if he had patented his discoveries. But he refused to make money out of his ideas, holding to the noble conception that a true man of science should work freely with the sole aim of increasing the knowledge, power, and welfare of the human race.

To escape from the melancholy of his soul — a melancholy caused, perhaps, by the fact that he was a man of a soaring spirit imprisoned in a blind, dead, mechanical universe that he had himself constructed — he tried to drug himself with work. He was indeed the most hard-working man of his age, and as he grew older his passion for work increased. Not content with his constant labors in three departments of chemistry, he took up the study of electricity, and was the first to attempt to apply it to growing crops. The science of thermochemistry is largely based on his observations. His lectures on science at the College of France went on for forty years and more, and all this time he directed and helped in the researches of his pupils.

Having always been a Republican of an impassioned kind, he took no part in political life under the Second Empire. But he was one of the forces behind the Third Republic, and he shed luster on the government of his choice, by acting first as Minister of Education in 1886 and 1887, and taking over the conduct of Foreign Affairs in 1895. When his scientific jubilee was celebrated in 1901 by a great public State function, all the world attended to do him honor.

Berthelot died March 18, 1907.

CLAUDE LOUIS BERTHOLLET
The Tragedy of a Great Man

CLAUDE LOUIS BERTHOLLET, one of the most famous French chemists, was born at Talloire, near Annecy in Savoy, December 9, 1748. Belonging to a family remarkable for its ingenuity and its poverty, he took up the study of medicine as a means of livelihood, and received the degree of doctor from the University of Turin at the age of nineteen. For four years he stayed at Piedmont, and than went to Paris, where Tronchin, the most famous physician of the age, who had great influence at the French Court, was struck with the talents of the starving young doctor, and obtained for him some noble patients, together with the freedom of the chemical laboratories in the Palais Royal.

BERTHOLLET VISITING LAVOISIER

Medicine was merely regarded by Berthollet as a means of existence. His real passion was for chemical study, and in 1784 he was appointed director of the royal dye-works. He was one of those men of commanding genius who do not wait for favorable opportunities, but create them. Introducing chemical science into an industry that dates back before human memory, he astonished the world by making the first striking application of scientific ideas and methods to a traditional branch of work. At that time the bleaching of fabrics preparatory to dyeing them was a long process. The cloth was washed many times, and after each operation it was spread on a field so that the air and light and dew would slowly take the color out of it. Berthollet, in 1785, worked out the modern method of rapidly and completely bleaching fabrics by means of a preparation of chlorine, thereby revolutionizing the dyeing industry, and he gave also an admirable example of the disinterestedness of men of science by throwing his invention open to the world and doing all he could to get men to use it freely without personal profit.

His chemical work, however, made him popular as well as famous; and at the height of the Revolution he was regarded by all parties in France as one of the sources of wealth and strength of the country. Continuing his researches on chlorine compounds, he came upon the highly explosive potash combinations. As these were much stronger than gunpowder, he attempted to experiment with them as a propellent for firearms. The essay was made in the presence of the director of gunpowder manufacture and four other persons. But the explosion destroyed the building and buried the spectators beneath the ruins. The disaster led Berthollet to reject the use of his new explosive, which went off with such murderous facility. But as the French Republic was in great danger from its enemies, he continued to risk his life in the search for new explosives and, at terrible peril, discovered fulminating silver, and then helped the government in other experiments and their chemical application.

He looked to the qualities of the soldiers' ammunition, sought for fertilizing chemicals to improve the crops of the country, and went to Italy to collect for the government the masterpieces of the great Italian painters, and discover more scientific methods of cleaning the canvasses. In Italy he met the young General Bonaparte, who became greatly attached to him. His practical achievements so convinced Napoleon of the value of science that he became a pupil of the chemist, and attended his lectures on returning to Paris.

It was to Berthollet that Napoleon confided his secret plans for an expedition to Egypt, and asked him to collect a band of men of science to accompany the army. Bread-making, beer-making, gunpowder manufacture, iron smelting and steel tempering, the erection of hospitals, and the establishment of a botanical garden were a few of the tasks that the brilliant young chemist helped to direct while following Napoleon in the Egyptian campaign.

In 1804 Napoleon made Berthollet a senator and conferred on him the title of count, but in spite of the Emperor's many favors he voted for his deposition in 1814. He was made a peer of France on the restoration of the Bourbon kings.

Berthollet aimed at reducing all the phenomena of chemistry to physical laws, and he was most successful in dealing with the decomposition of salts by acids. He was a follower of the great French chemist Lavoisier, and with him reformed the terminology of the science. Most of his writings are remarkable for their clearness, for their scientific importance, and for their usefulness in arts and industries. He died on November 6, 1822.

JÖNS JAKOB BERZELIUS
A Discoverer of Facts and Laws

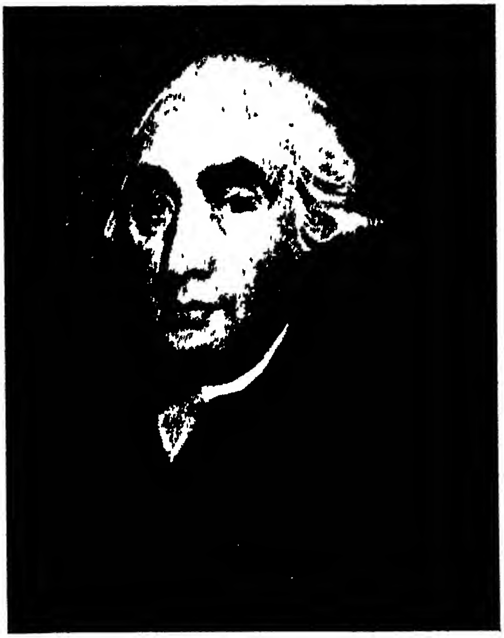
BARON JÖNS JAKOB BERZELIUS, who developed and enriched chemistry in its most important branches as hardly any other man has done, was the son of a schoolmaster of East Gothland, Sweden. Born on August 29, 1779, on a farm at the village of Väfversunda, he was left an orphan at the age of nine, and in his youth had to endure many cares and privations. While still a boy he acquired a love of chemical research, and, after many difficulties and disappointments, was able to complete his education at Upsala University. Unfortunately, the teaching he received in chemistry was dull and uninspiring. So he turned to the study of medicine, and graduated as a doctor in 1802. In the meantime, however, he kept up as a hobby the study of chemistry, and by his own unaided efforts obtained a practical and experimental knowledge of the young science.

An early work on the action of an electric current on salts made him famous at the age of twenty-two, and in 1802 he was appointed assistant professor in medicine, botany, and the study of drugs at Stockholm. His salary was small, but he added a little to his income by medical practice. In 1815 a chair for chemistry was found for him at Stockholm, and he broke away from the Continental tradition of giving lectures on pure theory, and attracted students by his illustrative experiments. In his modest home he installed a tiny laboratory, and in this humble chamber, hardly more than a closet, laid the basis of a large part of modern chemistry.

In 1823 the famous German man of science, Friedrich Wöhler, journeyed to Stockholm with a view to spending a winter in Berzelius's laboratory. Naturally he expected to find a well-appointed room, fitted with all manner of ingenious instruments. He knocked at the door of the house, and it was opened by a tall man with a florid complexion. It was Berzelius, the most famous of European chemists.

Asking if he might see the laboratory where so many mighty discoveries had been made, the astonished German was conducted to a little place off the kitchen, where there were a couple of plain tables, a blowpipe, a shelf or two of bottles, and a barrel of water for washing the laboratory dishes. In the kitchen in which the cook was working, were a small furnace and a sand-bath, and this completed the outfit of the man who had revolutionized a science.

Here the atomic weights of the greater number of the elements had been accurately determined New elements had been discovered, and the properties of uranium and platinum and the rare earths now used in incandescent mantles had been examined. No chemist has added to the science so many carefully determined facts as Berzelius. He was always at work in his little laboratory, and, in spite of his primitive appliances, he worked with the most exquisite skill. He was one of those workmen of genius who can make up in inventive power for the lack of tools and the money to buy tools. Berzelius indeed made, just for this reason, most ingenious advances in the technique of the chemical laboratory.



JOSEPH BLACK

Great as he was as a discoverer of facts, he was still greater as a discoverer of the laws that connect facts together, and point the way to larger fields of knowledge. His inventive output was not, perhaps, so great as that of his great contemporary, Davy, for he lacked appliances. But by strict methods of procedure and incessant study and observation he built up a theory of chemical porportions, which formed the foundation for the work of other men.

JOSEPH BLACK

Founder of the Real Science of Chemistry

JOSEPH BLACK, one of the founders of scientific chemistry, was the son of a Belfast wine-merchant. He was born near Bordeaux, in 1728, and his childhood was passed in France, but at the age of twelve he was sent home to Ireland to school and, in 1746 to the University of Glasgow. There he resolved to follow a medical career, and at the same time he began to take an interest in chemistry. But it was at Edinburgh University, where he went to complete his medical studies, that the young Irishman revealed his genius and founded the real science of chemistry.

At the time many medical men were using quicklime and potash, in the form of caustic potash, to counteract stone in the bladder. It was thought that when limestone was treated with fire the quicklime so made derived from the fire a "fiery power." This fiery power the quicklime handed on to the potash, and that was how the caustic potash acquired its power of corroding animal matter! Black resolved, in the ardor of youth, to go in pursuit of this "fiery power," and lay hold of it. For three years he delayed taking the degree of doctor of medicine, in order to make sure that his experiments were complete and his conclusions well founded. Then, in his famous thesis for the degree, he dismissed the fiery power into the limbo of mad fancies, and showed that the causticity of lime and alkali is due to the absence of the carbonic acid which was present in the limestone and certain forms of alkali.

The work that Black completed when he was twenty-six years of age is the first accurately quantitative examination of a chemical action which we possess. By it he began the high task of transforming chemistry from a fanciful, weak, and obscure art into a methodical science of universal range and tremendous power over the lives of men. Happily, his worth was at once recognized, and in 1756 he was appointed professor of anatomy and lecturer on chemistry in Glasgow University.

This post enabled him to form and train a school of young, scientific chemists. Among his pupils was James Watt, who remained his friend for life; Adam Smith, the famous economist, David Hume, the celebrated thinker; and Dr. Hutton, an early geologist.

At Glasgow, and later in Edinburgh, Black was more concerned with the methods and principles of chemical science than with the discovery of new facts. He wanted to forge the instruments of research, and train the men of the younger generation in the use of them. Unlike many highly original minds, he had a gift for teaching; and he delighted in exercising it. In his lectures he threw new light on the whole range of chemical science. From him men like Watt caught the fire that led to great achievements.

His own finest piece of experimental research was that on latent heat. This occupied him from 1756 to 1761. He melted a piece of ice to water, and then turned the water to steam He measured the amounts of heat required in these two operations. He showed that the heat was absorbed by the ice and the water, and that it was restored to surrounding substances when the steam again became water and the water congealed to ice. This kind of heat he called latent heat, because its presence was not revealed by the thermometer. Watt assisted him in his final experiments with steam.

In 1766, Black was appointed professor of chemistry at Edinburgh, and as such he remained till his death, on December 6, 1799.

ROBERT BOYLE

Hero, Thinker and Inventor

ROBERT BOYLE, the father of chemistry, was the fourteenth child of the Earl of Cork. He was born at Lismore Castle, Waterford, Ireland, on January 25, 1627. In boyhood he nearly lost his life through the mistake of a careless apothecary. This accident led him to the study of drugs and he acquired an interest in the chemical art of preparing them; and if he did not completely turn this art into a science, he at least laid the foundation for its scientific development.

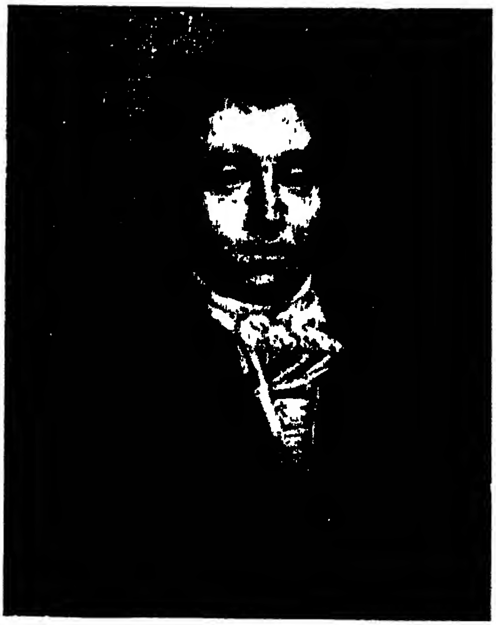
Boyle took no part in the political strife which he found rampant in England when he returned in 1644, after six years on the Continent, but became one of the little band of inquiring minds which used to meet weekly at each other's lodgings in London or at Oxford, Boyle's house being from 1654 the usual meeting-place, and from which grew the Royal Society, which was incorporated by Charles II in 1662, with Boyle among the members.

Boyle began his chief experiments in 1659, with the construction of his famous "pneumatical engine." This was an ap-

ROBERT BOYLE

paratus for creating a vacuum, and studying the properties of the air. He was very cautious in drawing conclusions from his experiments, as befitted a man who printed in 1661 a work entitled "The Sceptical Chymist." But through his caution and his thoroughness of investigation he was able to formulate the law of gases known by his name, which is of supreme practical importance in the design and working of steam engines. His "Sceptical Chymist" contains a greater number of well-authenticated facts than is to be found in any other treatise of its day. Boyle made alcohol from wood, and acetone from lead and lime.

Born in the year after Bacon's death, he is the first true exponent of the Baconian method. His fame and his social position made his personal influence very considerable, and the work that he did to advance scientific knowledge was of high importance. He was the coiner of the technical term "chemical analysis"; and by his discoveries of many means of discerning the presence of known chemicals in unknown compound substances he did much to forward that branch of the new science of which he was godfather. Some traces of the superstitions of the medieval alchemists clung to his mind, for, like Bacon, he was inclined to believe in the transmutation of gold.



SIR DAVID BREWSTER

Boyle was only skeptical in matters of scientific theory; in those of religion he was a profound and impassioned believer, and he established in London the "Boyle Lectures" in defense of Christianity. He died on December 30, 1691.

SIR DAVID BREWSTER
The Inventor of the Kaleidoscope

SIR DAVID BREWSTER, the eminent Scottish physicist, was born at Jedburgh, on December 11, 1781, the son of the rector of the local grammar school. Destined by his father for the Church, at twenty-three he preached his first sermon, but the strain was too great for his nervous system, and he reluctantly abandoned the pulpit for the editorial chair and the post of tutor.

Before he was thirty, he had begun that long series of investigations of the properties of light and of optics which brought him fame. He improved the stereoscope of Wheatstone by introducing refracting lenses, and invented the kaleidoscope, which for a century has been sold as a toy, but also has its practical uses in pattern designing Owing to an error in the patent specification, the inventor never obtained a cent from it. In 1816 his experiments on the polarization of light by successive reflections between plates of glass brought him the Copley medal, and soon after he became a fellow of the Royal Society, which later awarded him the Rumford gold and silver medals. He was knighted in 1831 and granted a government pension.

A prodigious worker, Brewster edited various educational works, contributed an enormous number of articles on scientific subjects to the reviews and encyclopedias of the day, wrote admirable biographies of scientists, introduced important improvements into the lanterns of lighthouses, examined and explained the nature and cause of color-blindness, from personal observation of his friend John Dalton, in whom the infirmity was first discovered, and helped to found the British Association, of which he was one of the first and most honored members.

He marched out with the 474 protesting ministers who quitted the Church of Scotland, and in doing so nearly lost the principalship of the united colleges of St. Salvator and St. Leonard in the University of St. Andrews. He was a member of the Royal Academies of St. Petersburg, Stockholm, Copenhagen and Berlin; an associate of the French Institute and of the National Academy of Sciences of the United States. His books include "Letters (addressed to Sir Walter Scott) on Natural Magic," "More Worlds than One," and "Martyrs of Science," referred to above. He died on February 10, 1868.

ROBERT WILHELM VON BUNSEN

A Great Developer of Chemistry

ROBERT WILHELM VON BUNSEN, to whom chemistry is indebted for a great number of important researches in every part of the science, was born at Gottingen on March 31, 1811. Among his inventions of a more general kind are the Bunsen burner, the magnesium light, and the Bunsen cell. He also took a chief part in founding the science of spectrum analysis. Educated in Göttingen and in Paris, after holding a series of professorships in different parts of Germany he was called, in 1852, to Heidelberg. For many years he remained the master-mind of this university, which he made one of the great scientific centers of Europe.

At the age of twenty-six he began his first important research, and for six years he studied a certain compound of arsenic. He made his name over it, but came out with the loss of the sight of one eye through an explosion, and after being nearly killed by arsenical poisoning. His early study of the gases given off by blast furnaces was of great practical importance. He was able to show that in German furnaces almost half the heat yielded by the fuel was allowed to escape with the waste gases, and that in England 80 out of every 100 heat-units went up the chimney with the waste fumes. This striking application of the principles of chemical research to an important industrial problem served to awaken the ironmasters to the high practical value of modern science, though many years passed before they learned to convert the waste gases from blast furnaces into a source of power.

Bunsen also invented the carbon-zinc electric battery, now generally known by his name. By using it to produce an electric arc, he obtained out of a pound of zinc a light equal to nearly 1200 candles. Each pound of zinc used in the batteries lasted an hour. Then, in order to measure exactly the amount of light that he so obtained, he invented another instrument, the grease-spot photometer, which remains still in general use.

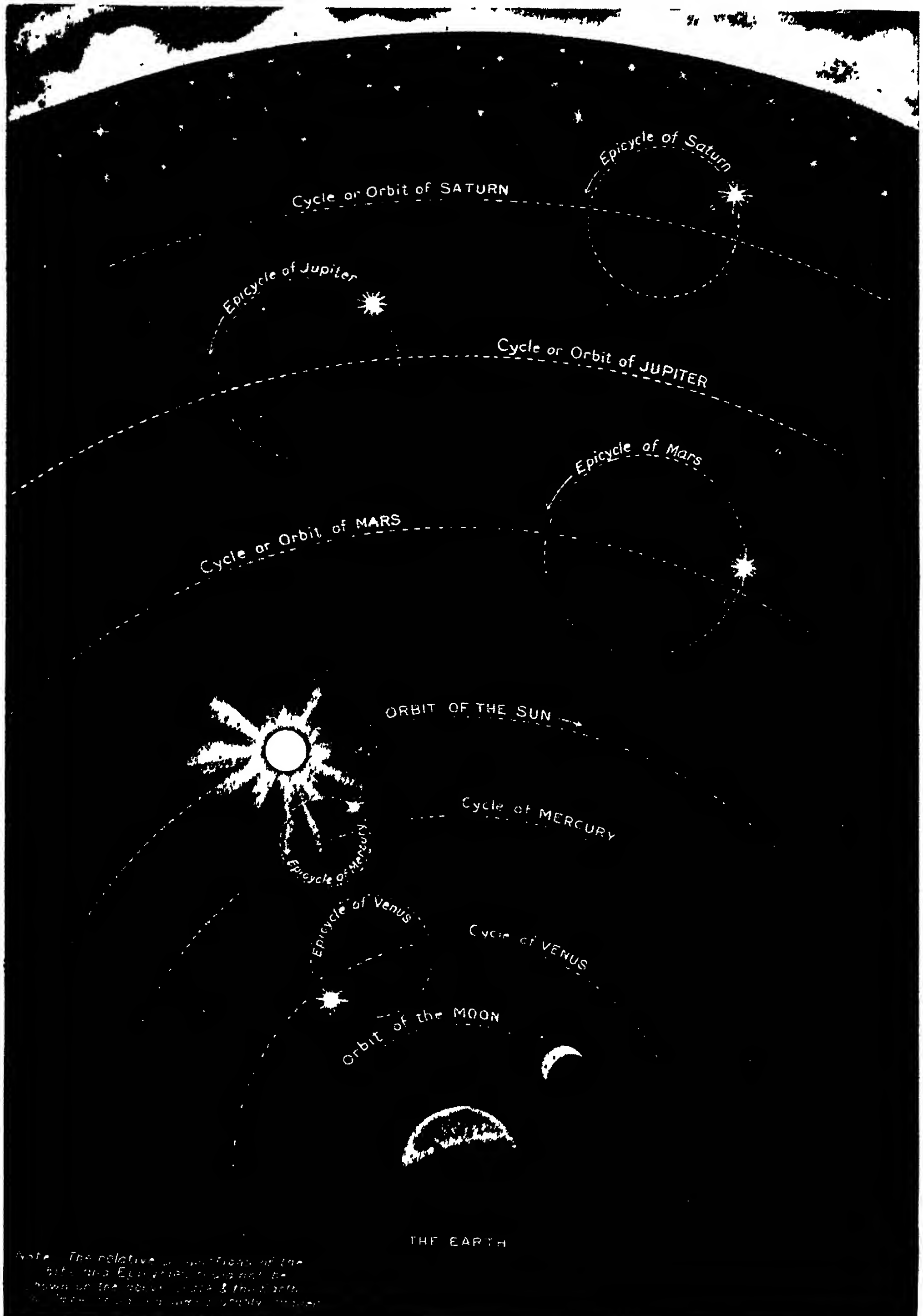
In 1852 Bunsen began to use his battery in another ingenious way. He sent the current through various solutions, and separated the substances therein. By this means he obtained magnesium in its metallic state, and turned his discovery into a matter of importance to photographers by studying the properties of the magnesium flashlight, and proving how quickly it acted on a photographic plate.

The famous Bunsen burner was invented by him as an aid to chemical research. In 1855 a new laboratory was built at Heidelberg, and Bunsen was asked to look at the various devices proposed for supplying heat for use in chemical operations. A blowpipe was generally employed for the purpose, but Bunsen wanted something more convenient to handle. Finding nothing to suit him, he quickly devised a simple means of burning ordinary coal-gas in such a way as to produce a hot smokeless flame. His burner was so excellent and easy a means of obtaining an intense heat that it has come into general use.

Bunsen was remarkable for his dislike of theories; he never troubled about them, even when the chemists of Europe were divided into two warring camps, each with a separate theory. He kept to facts, and especially to the discovery of new facts, and new methods for arriving at facts. The result is that the only book he published, which was on gas analysis, is as sound today as when it was written; it is not only a storehouse of information, but it practically still covers the whole field.

Bunsen was so continually successful a man of science that we cannot attempt to enumerate his discoveries. There is, however, one achievement of his so tremendously important that it dwarfs all others. Following a strange discovery made by a fellow-worker in 1860, he took a main part in the finding out of the significance of the thousands of faint dark lines seen on the band of colors formed by passing sunlight through a three-sided piece of glass. By developing his methods we are now able to get photographs of iron-storms and other whirling masses of flaming elements on the sun. Bunsen died at Heidelberg on August 16, 1899.

WHEN ALL THINGS MOVED ROUND THE EARTH



Before the days of Copernicus and Galileo scientists explained the movements of the heavenly bodies by the system of Ptolemy depicted in this drawing The earth was held to be stationary, while around it, once each day, revolved a vast sphere, or rather a set of concentric spheres, to the inner surfaces of which the sun, moon, stars and planets were fixed The old astronomers, however, noticed an irregularity in this motion in the case of the planets, and elaborately calculated that each planet also revolved in a small circle, or epicycle, of its own.

THE MAGIC OF MOTION

Some of the Stupendous Facts that Newton and Galileo Found and Missed While Studying

THE UNCHANGING LAWS OF EVERYWHERE

THE law of gravitation is truly universal, we have seen, and stands as a great instance of such laws, but it is not alone. though it holds by far the most important and predominant place among the "prime movers" of bodies, both heavenly and earthly, it still remains only one of them; and in dealing with general astronomical theory it will be necessary to consider the relatively slight effects of other forces such as radiation pressure, or magnetic attraction and repulsion, which in their cumulative action may considerably modify, after long ages, the course of the planets and the balance of the various celestial systems which may claim our attention. It follows that we have much to learn yet before we are entitled to take up the study of any particular part of the heavens — that is, understandingly

All things move, stars compared with which the sun is a spark, or the ultimate specks of which this paper is composed. Living things move, as all others do. We express our will and character by moving things — portions of ourselves, or things outside us. We may demur to these assertions, and quote instances of rest But it is doubtful whether any physical being in the universe is really at absolute rest.

It is plain, in the first place, that when we speak of motion we are always thinking of something that is actually relative. Certainly there might be one single particle of substance, alone in infinite space, and there does not seem to be any reason why it might not move. Whatever motion it might make would be absolute, not apparent, not relative to anything. It certainly seems that there must be real absolute motion. But in this imaginary case, since we could observe it from nowhere, the absolute motion of this particle would be beyond sensible detection. Not being relative to anything, it would not be apparent to us; but, of course, if we were "there," or anywhere, we could observe the point's motion at once, for then we should have ourselves and our position to measure it by — it would move to us, or from us, or past us. Thus we establish two great ultimate propositions: there is absolute motion, but all the motion we actually know or can measure is relative.

And evidently what is true of motion is true of rest. We are entitled to imagine absolute rest if we are entitled to imagine absolute motion Our solitary speck in space may move, or it may not move: but whether or not there are actually any bodies at absolute rest we cannot say, for all our means of observation merely enable us to perceive relative rest.

That motion is a dominant fact of nature, or a universal condition of all physical things we see at once when we look into any supposed case of rest. Not one that we can adduce will stand the test of inquiry; there is always some unbalanced force at work, producing a motion which we had forgotten, and which is none the less real though we cannot see it. This page may appear to be at rest, but consider any portion of it, and we find it is not so. It "rests," perhaps, upon a table. The gravitation between it and the earth makes a downward stress, which we call its weight; this the table resists, and so the book rests. Yet, in the first place, all its parts are so in motion.

Motion the dominant fact alike in worlds and in atoms

The book has a temperature, for, however cold the day, it is certainly nowhere near the nadir of cold at which no heat exists The heat of the book involves a certain special movement of all its parts Again, the paper consists of atoms, and each of these, we are now persuaded, is a kind of solar system in miniature, with multitudes of lesser particles within it, which appear to be moving at a tremendous speed.

But that is only the beginning, and it might be argued that it is not a fair beginning, for we began by talking of the page as a whole, and we have produced no evidence against the view that that is at rest. Yet we are under a huge delusion, due to the almost irresistible tendency to judge everything by ourselves. Relatively to us, the book is at rest, but neither book, nor we, nor walls, nor floor is at rest For instance, the earth appears to be steadily, however slowly, shrinking — partly, perhaps, in virtue of its own gravitation, and partly in consequence of its slow loss of heat.

The enormous complexity of the combined motions of things

Thus it seems that book and house and foundations and earth's crust are sinking as a whole; and, on the other hand, the students of the earth will assure us that its crust rises and falls owing to local causes, so that there may be forces now at work which are raising our house and book, and they would need to be measured, if it were possible, against the more general causes of subsidence due to earth-changes as a whole. Whatever is happening in that respect, we know our house, book and selves are in motion, because the surface of the earth is in ceaseless motion, due to the rotation of the earth about its axis; and if we happen to be on the equator we are traveling some twenty-five thousand miles every twenty-four hours unceasingly. Further, the entire earth, as it spins, also flies round the sun, somewhat faster when nearer to it, somewhat slower when farther from it, as Kepler taught us, but always with a speed of many miles in every second. Lastly, or, rather, lastly so far as we know, the sun itself is in motion, we and our book with it, also with a speed of many miles a second. So much for what we thought to be rest Even so, no one can say anything of the absolute motion of the sun, and therefore of ourselves We can only observe the stars, and compare their apparent motions, and say that, relatively to certain stars or groups of stars, the sun appears to move in such and such fashion.

But what the stars in question are really doing themselves we cannot say, and thus we find ourselves in the position of those who daily see the sun rise in the east and set in the west, and infer therefrom that it revolves round the earth. They can only judge of apparent motion, and their verdict is just the reverse of the truth, because that which they assumed — namely, the motionlessness of themselves — is the reverse of the truth.

The tremendous problems the astronomers have not yet begun to answer

We do poor credit to the facts of astronomy, or to the skill and courage which astronomers bring to their tremendous problems, if we fail to realize how tremendous they are People expect astronomers to tell them where and how and why the sun moves, whether it is moving in a straight line or in a curve, whether or not that curve is closed, so that, like ourselves round it, it is describing an orbit round something else. They would expect less if only they realized that our study of motion can only be relative; and they would respect more what the astronomers can give them. No one can say what the Milky Way or Galaxy is doing as a whole, or whether it is doing anything as a whole. Its constituent stars are certainly in motion, in various directions, as the planets of the solar system are in motion, in various directions which are yet orderly. It may be that the Milky Way is a whole, as the solar system is a whole or as an atom is a whole. The Milky Way may be in rotation, for all we know, though in what direction, at what speed and moved by what forces we know not.

So far already have we traveled from our forefathers' idea of the "fixed stars", and that is not all It is one of the theories of many modern astronomers that our stellar "universe," or system, is only part of the whole universe, just as the solar system, say, is only part of it. There are real outward limits to the distribution of the stars we know, so that they constitute a system; or possibly the stars we know belong to two such systems, moving past and through each other in opposite directions. We are thus entitled to form the idea that the whole known "universe" — but the term will now require reconsideration — is in motion, and that motion may be of any kind, for all we know. motion in a straight line, motion of vibration, like that of a pendulum, or motion in an orbit. More precisely, it may be the case that the overwhelming majority of all the heavenly objects we know belong to such a system, moving as a whole, or to two such systems. On the other hand, certain objects, such as the great nebula in Andromeda, we now suspect may belong to a different starry system altogether, or may constitute such a system.

The history of the immeasurably gigantic movements of the heavens

The modern study of the distance of the nebulæ affords results so inconceivably stupendous that the real dimensions of such a body must vastly transcend anything the mere photography or contemplation of them could suggest; and they may be what we are almost tempted to call "universes" in themselves, and in motion, like all things else. What we have hitherto called the starry universe may be only one starry system, or the temporary confluence of two such systems, the like of which may exist in any numbers in space. Any or all of these stellar systems may be in any kind of motion as a whole, quite apart from the number and variety of the motions of suns and solar systems and atoms and electrons within it.

Now, all motion is inseparably bound up with energy, and every moving body displays and obeys the laws of energy in general.

The mere magnitude or the distance or the speed or duration of any motion is of no special significance here, the laws which govern and are illustrated in the movements of a star, a comet, a "falling star," a baseball, or an electron are absolutely identical. This, also, is one of the ultimate facts of the universe; and has the practical consequence that our study of moving bodies upon the earth may guide us to comprehend and predict the otherwise immeasurably gigantic movements of the heavens.

We know enough already to realize that the laws of motion must certainly "square" with what we have already learned of the laws of energy, since energy is inseparably bound up with motion and is necessarily increased or decreased as the motion of a body is increased or decreased. Since this is so we are somewhat surprised by the remarkable historical fact that Newton, who formulated the laws of motion, somehow missed the doctrine of energy and its conservation, though he seems practically, or subconsciously, to have realized it, and though it can readily be deduced (now we know!) from his own laws.

The three great laws that underlie all motion and cannot be ignored

Newton's three laws of motion in general, not to be confounded with Kepler's three laws of planetary motion, are:

1. Every body remains in a state of rest, or of uniform motion in a straight line, unless it is compelled by impressed forces to change that state.

2. Change of motion is proportional to the impressed force, and takes place in the direction of the straight line in which the force acts.

3. Action and reaction are equal and opposite; or the mutual actions between any two bodies are always equal in magnitude, but oppositely directed.

These three brief statements have the most gigantic meanings and consequences. They are always and everywhere true, and they underlie, at every point, the processes by which modern physicists and astronomers pursue their arguments and inquiries to successful conclusions.

The law of rest or inertia that is really a law of motion

The first law is the law of inertia, which illustrates and justifies much that we have already said Observe, first, that the law applies equally to rest or to uniform motion — as was to be expected if we were right in saying that rest as well as motion is the result of the interaction and balance of forces, which amounts to saying that rest is a special case of motion. What the law asserts for and of the one it asserts for and of the other. Commonly we accept it and admit it only as regards rest. It seems reasonable to us that a body at what we call rest should remain in that state until something moves it. That is because our minds, when reasonable, cannot believe in the making of energy (such as motion involves) out of nothing. But many of those who accept this part of Newton's first law, and thus of the law of the conservation of energy, do not accept its second part, which also corresponds to the second part of the law of the conservation of energy. They are so accustomed to the arrest of moving bodies that they think it more or less spontaneous.

It is not so: no moving body will do anything but continue in motion in a straight line at unchanged speed forever, unless something stops it. That something may be only the resistance of the air, which we do not see, but it is real nevertheless. The law of inertia is equally and indifferently true of rest and of motion.

A repelling power in the universe that Sir Isaac Newton never knew

One most remarkable and novel observation has been made in very recent years, which must be considered here as it may affect the motions of many and perhaps of all the heavenly bodies.

Sir Isaac Newton showed how the single universal force of gravitation was competent to account for all the observed motions in the heavens. This is in the main true. However, there are some astronomical facts which are hard to reconcile with simple gravitation. Thus we have the curious phenomenon that when a comet in its orbit approaches the sun it develops a tail of considerable volume and often millions of miles long This tail is directed away from the sun no matter what may be the direction of the comet's motion. It would appear therefore that the tail is repelled rather than attracted by the sun The comet's tail is surely composed of some kind of matter and the sun must exert an attraction on it as it does on other material bodies. But it does something more than this. It also pours upon it a flood of radiation in the form of light and heat. Now shortly after the middle of the nineteenth century, long after Newton's time, Clerk Maxwell showed that according to his new electromagnetic theory of light sunlight should exert a pressure on any surface upon which it falls. He calculated the magnitude of this pressure and found that it was very minute, in fact, less than a milligram per square meter of polished surface. These conclusions of Maxwell were purely theoretical, but in the beginning of the twentieth century this pressure was actually detected by Levedew in Russia and later in America by Professors Nichols and Hull, who made use of improved methods for detecting and measuring it. Their investigations confirmed Maxwell's conclusions.

It follows therefore that the sun not only attracts bodies according to Newton's law of gravitation but it also repels them in virtue of the pressure of the radiation it sends to them. Ordinarily the radiation pressure is masked by the immensely more powerful gravitational attraction. In the case of small bodies conditions may be different. For we know that at any given distance the attraction of the sun upon a body is proportional to the mass and the mass varies as the cube of the linear dimensions of the body. On the other hand the repulsion due to radiation pressure is proportional to the surface which varies as the square of the linear dimensions. If now we diminish the size of the body, the mass will diminish more rapidly than the surface so that eventually repulsion may preponderate. This fact at any rate explains very plausibly why a comet's tail is directed away from the sun.

The retarding of the everlasting circling of the heavenly bodies

The tail is doubtless composed of small particles and the light pressure may be sufficiently great to overcome gravitational attraction While it may not be altogether certain that the light pressure is great enough to account for the phenomenon, the fact remains that the sun and the stars do exert a real pressure upon the bodies which receive their radiation If the star is in motion other interesting complications arise Thus if the star is approaching the earth more radiations are received in a given time than when it is receding The character of the light as observed in the spectroscope will vary. In the first case the spectral lines will be shifted towards the violet and in the second case towards the red We meet a similar phenomenon in the case of sound. Thus the pitch of a note produced, say, by a locomotive rises as the locomotive approaches and falls as it leaves us. There is a simple relationship between the speed of the locomotive and the change of pitch as also between the shift of the spectral lines and the speed of approach or of recession of a star. Astronomers are thus able to measure the motion of stars in the line of sight, that is, when moving directly towards or directly away from us Other complications may arise in the radiation-pressure when the radiating body is in motion which may modify the effects of gravity Needless to say, Newton's first law remains true, but wherever there is a heated body, as is the case of so many millions of celestial bodies including the sun and all the bright stars, we must realize that there is a source of energy, the effects of which are opposed to those produced by gravitation and hence will result in retarding to some extent the motions of countless other celestial bodies. No doubt radiation-pressure is a force of very small intensity, compared with many that we have known longer, but if it be constantly producing any retardation, however small, and if "the time is unending long," the cosmic results may be past our skill to imagine.

Fortunate are we small folk, standing on Newton's shoulders, thus to see further than was vouchsafed to him We know radiation-pressure, as he did not, and one of its most notable consequences, and we are able to read his first law of motion, the enunciation of which was a great feat of scientific induction, and to see at once that it necessarily consorts with the greater law of the conservation of energy, which Newton did not quite know, but which is almost hackneyed to us.

How we measure the force of gravity

Immensely important, from the point of view of practice, prediction and research, is Newton's second law. In declaring that the change of motion produced by any force is strictly proportional to the magnitude of that force, Newton laid down the principle whereby we can measure forces. By the term "motion" is here meant not simply the velocity of a body, but the product of the velocity and the mass of the body; this is now called the "momentum" of the body and Newton's second law may be more clearly stated in Maxwell's formula: "change of momentum is proportional to the impulse which produces it and takes place in the same direction." If we measure the mass that any given forces move, and the change of velocity they induce, we have an absolutely trustworthy means of measuring their magnitude. This is, indeed, the way in which we identify forces at all: and since Newton's second law will never fail us, we can compare and balance different forces by means of the motion they produce.

This principle, afforded by Newton's second law, enables us to measure the force of gravity, which he also revealed to us. We can observe the motion of the falling body, and see how many feet it falls in the first second, how many in the next, and so on; and from these observations, repeating and adding to those made long ago by Galileo, we can state the force of gravity at the surface of the earth, at the equator, or at any other point we choose. We find—need it be said?—that gravity, constantly acting, constantly adds to the motion of a falling body.

Thus, the longer a falling body continues to fall, the faster does it move, the greater is the energy which gravity has imparted to it, and the greater, therefore, the force with which it strikes the ground. In our part of the world the speed of a body falling under the action of gravity increases by about 32.5 feet per second in every second during which the body falls.

The second law further states that the change of motion produced by a force occurs in the line in which the force acts. It is very important to note here that it is the *change of motion*, and not the total actual motion, that takes place in the line in which the force acts; thus the force of gravitation controls the orbits of the planets and this force always acts in the direction of the straight line joining the sun and the planet; the change of motion therefore must take place in this direction, but the total actual motion is never directly towards the sun but in a path around the sun. The reason for this is that the planet has had from the beginning of its history an original onward motion quite independent of the attraction of the sun; the actual motion of the planet in its orbit is the combination of this original motion with the ever varying motion imparted to it by the sun's attraction.

Motion almost always the result of the combined action of many forces

In most cases, and probably in all, not only one but many forces are simultaneously acting on any given body and Newton's second law declares that each force produces its due result, however many other forces be at work, and whether the body it acts upon be already in motion or at rest. This applies equally to the magnitude of the force and to its direction; and from this great consequences flow. For it enables us to add together any number of forces, of whatever magnitude, and acting in whatever direction, and to state unhesitatingly the exact speed and direction — or "velocity," to use the technical term — which they will together impress upon a given body. This process we may call the "composition of forces."

The calculation of the net magnitude of natural forces

But the "resolution of forces" is no less important. We may observe a case of motion, say, of a moon or a cannon-ball, or a jet of water, and may be acquainted with one or more of the forces at work. We can now subtract the motion due to them from the motion we observe, and thus, it may be, discover and measure forces hitherto unknown to us. It will thus be seen that Newton's second law is of scarcely less importance than the first.

The third law has already been illustrated in some degree, as it is involved in the recent study of radiation-pressure. There is no more familiar case of it than the recoil of a rifle when a bullet leaves it. We often see exactly the same thing when a fielder is returning the ball from the outfield, and we notice his whole body driven backwards as the ball leaves his arm. Similarly, when we strike a wall it strikes us; and the force acting along a tense rope, such as a towing rope, acts equally throughout its length, and in both directions, the same force being directed upon the towers as upon the boat they tow, though we may find this at first difficult to believe.

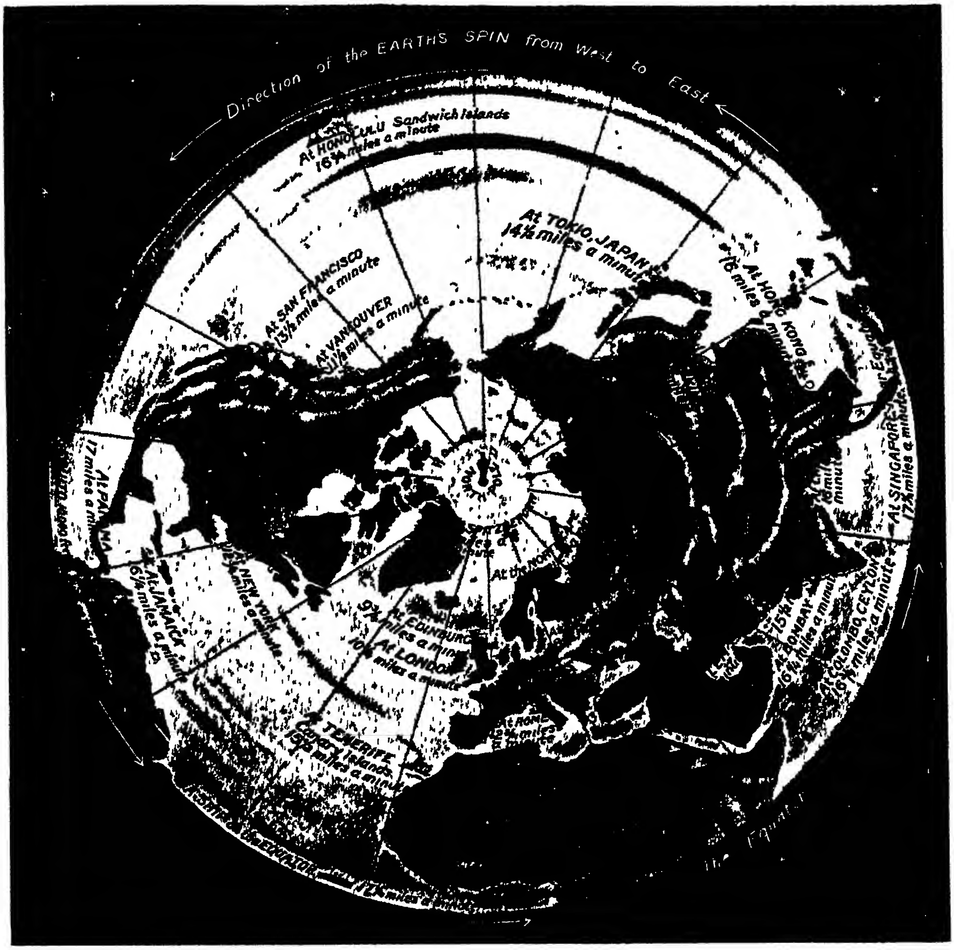
The infinite complexity of motion when rotation is added to onward movements

Such being the laws of motion, we may now observe that they apply equally to various forms of motion, which we must identify. When we were discussing absolute and relative motion, we were evidently quoting the cases of what is called "motion of translation," which is literally carrying-across. But though the motion of translation is what first occurs to our minds when we think of motion at all, there is a very different kind of motion which we call "rotation." We are already familiar with bodies, such as the earth, which exhibit both motion of translation and motion of rotation, and the sun exhibits both also. Rotation is, of course, the motion of a body round a point within itself. We should not confound the earth's diurnal *rotation*, correctly so called, with its annual *revolution* round the sun.

In studying concrete cases of motion; we find many that are extremely complicated — as, say, the motion of the earth, or the sun, and, still more, of the moon; but in every case the motion can be resolved into the two great types above named.

Upon Newton's laws can be built the whole science of forces, which is properly known as dynamics. This is of equal importance in theory, where it leads us to the doctrine of the conservation of energy, or in practice, where it guides the astronomer and the engineer with equal certainty. The subject is truly universal, for precisely the same dynamic assumptions are made, and justify themselves, whether we are studying the motion of a "flying star," or a conceivably minute electron.

It seems necessary here to remark that Newton's laws of motion and more particularly his law of gravitation were obtained as generalizations from a large body of observed facts and hence are in a certain sense experimental in character. Thus the assertion that any two bodies attract each other with a force varying directly as the product of their masses and inversely as the square of the distance between them is based on the observation of the motions of bodies near the surface of the earth, and the motions of the planets with their satellites, of the comets and of other members of the solar system; and the universal agreement between the facts observed and the law Newton deduced from the facts is the guarantee of the truth of the law.



MAP SHOWING THE RATE AT WHICH VARIOUS PARTS OF THE EARTH TRAVEL ROUND ITS AXIS

All physical measurements, however, are subject to a certain degree of indetermination, owing to the limitations of the instruments used in making them; it is therefore possible that Newton's law of gravitation is only a very close approximation to the absolute truth: for if the force of attraction between two bodies should vary inversely not as the exact square of the distance, but as a power of the distance differing from the square by an amount smaller than the smallest quantity we can physically measure, either directly or indirectly, then there would be no means by which we could decide the ultimate numerical accuracy of the law. Certain recent investigations tend to show that while Newton's law of gravitation and the system of mechanics based on it hold good for bodies moving with moderate speeds, there is a measurable deviation from this law in the case of bodies moving with very high speed, namely, with a speed approaching that of light, which travels 186,000 miles a second. These new speculations and investigations are involved in the Theory of Relativity, which has attracted such widespread attention and interest not only among scientists but also among all classes of educated persons. The theory, which owes so much to Einstein's labors and is commonly referred to under his name, is still in the formative period, and there is much disagreement among scientists not only as to the extent of its applications, but also as to its fundamental meaning and validity. Every effort is being made to secure the most careful and accurate measurements of those astronomical phenomena which offer the best experimental means of judging its true value. The near future may bring to the learned world sufficient data for forming a definitive judgment in the case. Whatever that verdict may be, it will in no way discredit Newton's great achievement, and the Newtonian system of dynamics, despite certain premature and inconsiderate statements to the contrary, will remain a marvelous triumph of human science and the practical basis of our organized knowledge and our scientific treatment of the vast majority of physical phenomena.

But our survey of Newton's work remains incomplete unless we look also at the work of one of his most illustrious predecessors, "the starry Galileo."

Newton and Galileo, the great discoverers of underlying principles

If anyone be asked at random to describe Newton and Galileo, the answer would be that they were astronomers We connect Newton with gravitation, and Galileo with the telescope But neither of these men would have been what they were had they kept their eyes only on the heavens. Their work, not least their work in that field, depends upon their discovery of laws, first observed on the earth, which apply everywhere. Galileo is Newton's precursor in the foundation of the science of dynamics, which underlies all modern study and understanding of the balance and the motions of the heavens.

We are familiar with the idea expressed as "center of gravity," and can realize that the center of gravity of a body must also be the center of its mass — the point around which its mass is equally balanced. Observation on this subject was open to anyone who knew that bodies fall — and Galileo was the pioneer here, as in many other respects, always illustrating the practical principle of the experimental sciences that we should determine the laws of physical phenomena not by *a priori* reasoning but by actual observation and coordination of the facts of nature as they daily happen about us.

Above all do we owe to Galileo the discovery of the law of falling bodies. In our reference to the force of gravity, and the acceleration that is the increase in speed it produces in falling bodies, we have stated the very simple facts, but we have ignored the complications which beset them, and which Galileo removed.

The truth is that we have quietly set aside, as insufficient, the authority of Aristotle, which ruled the world with unquestioned sway for nearly two thousand years, until Galileo showed that a number of so-called physical laws supported by this authority were based more on speculation than on accurate observation of facts.

The strange mistakes of ancient philosophers which Galileo corrected

Let us look at some of the ideas which our ancestors accepted from the mouth of the great Greek, and from which Galileo delivered us, thus preparing the way for Newton and others and taking many great strides along it himself

Notwithstanding gravitation, a bladder rises in water, or a balloon in air If we will think a little, we can now understand such cases, and see that they really illustrate the working of gravity; in any fluid subjected to gravity, such as air or water, the pressure in the lower layers is greater than in the upper, as each layer has to support the layers above it. Besides, the downward pressure at every point is just balanced by a corresponding upward pressure Now if we immerse a bladder in water the pressure acting on its upper surface will be less than that acting on its lower surface There will then be an unbalanced upward force acting on it tending to make it rise As was shown by Archimedes some twenty-two centuries ago this upward force is equal to the weight of the water displaced by the bladder, and since this is greater than the weight of the air-filled bladder, the latter will rise. In like manner a balloon will rise in air. Such motions as these depend upon the different density of substances, which we call their "specific gravity," and they not merely conform to the law of gravitation, but it would be no law if these apparently contradictory motions did not occur as they do. But Aristotle's explanation was that certain bodies have "gravity," and fall, and others have "levity," and rise. This is a false explanation; and even if the terms and their contrast were true, the explanation would only be the explanation of the action of opium given by Molière's physician, that the cause lies in the "sleep-giving property" of the drug.

From this incorrect view Galileo delivered us, though neither he nor any of his successors has been able to explain the nature of gravitation itself. Having, however, made this advance he went still further.

The sound discoveries that seem to contradict our everyday experiences

Indeed his mind never stopped when inferences were possible Surely the descent of any body in a medium such as water depends, as regards its speed, upon the comparative density of the body and the medium in which it moves Suppose, then, that we could observe bodies falling where there was no medium? "I have thought," said Galileo, "that if the resistance of the media be wholly taken away, all matter would descend with equal velocity." This was a tremendous assertion, and if we suppose it obvious, the chances are that we have not realized it

But it is a simple matter to make the experiment Every day we observe that different forms of matter fall at different speeds But if we take a long tube, remove the air from it as far as possible, and then allow a silver dollar and a feather to fall from one end of it to the other, we find that they arrive at the same moment.

We must now perceive that, when we asserted the law of gravitation, and when we stated the force of gravity, as measured by the motion it can induce, we were making very large and general assertions, which by no means agree with the superficial appearance of things. In that statement of ours, we said nothing about the consistence or the density of the falling body, but asserted a certain speed to be true of all falling bodies, whether their shape or consistence or density be after the fashion of a feather or of a silver dollar Perhaps we may now realize our debt to Galileo, whose work was indispensable for the subsequent enunciation of those constant and universal laws which now seem so simple to us.

Galileo's experiment from the leaning tower of Pisa that was never forgiven

But there was another question. If we take two bodies of the same consistence and density — which is obviously a different problem from that of the feather and the dollar. — and if we make one of them twice as heavy as the other, how will they then fall in comparison with each other?

In all our foregoing generalizations, we have said nothing of the massiveness of bodies falling to the earth. We said that they fall with a certain, exactly measurable acceleration, due to gravity, and varying according to the force of gravity at different parts of the earth or on different planets, and we have ignored the fact that bodies differ in massiveness. The fact is irrelevant, as Galileo proved.

Aristotle had said otherwise. The falling was due, in his view, to the gravity or heaviness of the falling body. If we double its gravity or heaviness, it should fall twice as fast, he said. Neither he nor anyone else tried the experiment, which is surely as simple and easy as can be. Aristotle had said so, and for nearly two thousand years that was enough.

Galileo, then at Pisa, declared that, but for the small difference due to the disproportionate resistance of the air, the two bodies, of different weight, would reach the ground at the same time. The followers of Aristotle — everyone, that is to say — laughed at him. "But Galileo was not to be repressed, and determined to make his adversaries see the fact as he saw it himself. So one morning, before the assembled University — professors and students — he ascended the Leaning Tower, taking with him a ten-pound shot and a one-pound shot. He balanced them on the overhanging edge, and let them go together. Together they fell, and together they struck the ground." We can imagine the surprise of the spectators, who so confidently relied on the universally accepted theory of Aristotle.

But undoubtedly there is a difficulty in understanding, at first, why this experiment should have resulted as it did. Surely, we say to ourselves, the force of gravity is greater when it is exerted between the earth and a ten-pound shot than when between the earth and a one-pound shot; and, if so, ought not the resulting motion to be proportionate, according to Newton's second law? Undoubtedly the reasoning is correct so far: greater force is exerted in the former case, and more motion, or, to use the more accurate term, momentum should be the result. Now momentum depends upon mass as well as velocity, being numerically equal to mass multiplied by velocity. And in this case the greater force is justified, for it is moving a proportionately greater mass; and the velocity is thus the same in both cases.

Galileo was not only a great mathematician and a great experimenter, but he was also a master of the deadly weapon of ridicule, which may be made a great servant of truth, but usually alienates those against whose errors it is directed.

One other discovery of Galileo's regarding motion, and we may pass onwards to the skies and their contents. It was that a vibrating pendulum performs its movements in the same time, whether they be large or small; hence the possibility of measuring time therewith. And as the story goes that Newton, at twenty-three, saw an apple fall, and guessed his great discovery, so they say that Galileo, at eighteen, in the cathedral at Pisa, watched a great lamp swing from the roof of the nave, timed the oscillations by means of his only watch — his pulse — and found them performed in equal times, whether they were large or small. We all have eyes and pulses, but do we make use of them as he did?

INSIDE THE EARTH'S CRUST

The Metals with which Man has Hacked and Blazed His Way through the Dark Jungles of Barbarism

A SURVEY OF THE LEADING METALS

WE have mentioned the substances that play the chief part in the constitution of the crust of the earth; but the earth's crust is full of a number of things that play other parts than mere crust-making, and are of particular interest to the living beings inhabiting the crust Chief among these interesting things are the metals. So important are metals to civilized man that some are used as milestones and landmarks of progress, and it is common to talk of the Stone Age, the Bronze Age and the Iron Age. With metals, indeed, has man hacked and blazed his way through the dark jungles of barbarism.

What is a metal? The term is too ancient to be scientific, and, though science uses it, science has not succeeded in giving it a very sharp and distinct definition But certain substances are put in one class and called "metals," because they have certain characteristics more or less in common. They are lustrous; they are good conductors of heat and electricity; they are usually rigid when cold, yet show a certain amount of elasticity. Most are opaque to light; but gold, if beaten out into very thin leaves, transmits green light, and thin films of mercury transmit light of a violet-blue color. Probably all are capable of assuming a crystalline structure, and some, such as zinc, show crystals quite clearly.

But perhaps the features that nearly induce and best justify the classification of metals are the properties of plasticity, malleability and ductility, which have rendered certain substances so useful.

The plasticity of metals, their capacity for being molded as a potter molds a bowl, varies in individual metals and depends on circumstances. Thus, potassium and sodium, even when cold, can be worked with the fingers like wax, and lead and thallium are also easily molded at ordinary temperatures Others, such as zinc, iron and lead, become readily plastic only when heated Even those hard metals which seem to lack plasticity are, however, really quite plastic, as was shown in quite a sensational way by H. E. Tresca (1814–1885), who drilled a cylindrical cavity in a block of steel and made a hole in the bottom of the cavity that reached to the exterior of the block. He then put little discs of metal into the cavity, and by means of a piston working under hydraulic pressure he subjected the discs to a pressure of over 200,000 pounds. Under this pressure even such a hard metal as iron was squeezed like putty through the hole in the bottom of the cylinder.

In some metals the malleability, or the capacity for being flattened into thin sheets by hammering or pressure, and ductility, or the capacity for being drawn out into wire without breaking, are most remarkable. Gold-leaf, for instance, can be beaten out till it is only a 280,000th part of an inch thick. A single grain of gold has been pounded out so as to have a surface of nearly 80 square inches, and platinum can be drawn out into a wire so fine that it would take 800,000,000 strands to make a cable one inch in diameter.

Metals vary in color: many are white or gray; but gold is yellow, and copper is reddish. Metals also vary in weight. Potassium, lithium and sodium are light enough to float on water. Silver, on the other hand, is more than ten times the weight of water, and platinum and osmium are more than twice the weight of silver. Each metal has its own characteristic melting-point. Thus mercury is solid only at very low temperatures and melts — or returns to its normal liquid state — when its temperature is allowed to rise to — 39° C. Potassium and sodium melt below the temperature of boiling water. Silver and gold melt at a temperature of 961° and 1063° C. respectively. Platinum requires a

IRON AS IT IS BROUGHT OUT OF THE EARTH

temperature of 1755° C. Tungsten melts at about 3000° C., the highest of any known metal.

The most important metals which are used in metallic form are iron, aluminum, copper, zinc, lead, tin, mercury, silver, gold and platinum. There are also many rare metals which have interesting special uses. Metals which occur chiefly in combined form will be discussed elsewhere.

It must not be thought that all the metals occur in a pure state in the crust of the earth. A few, such as gold and platinum, are found practically pure, but most of them are oxidized and mixed with foreign material, forming ore from which they must be extracted by various processes. We need not here discuss the metals individually, but the more interesting and important may be considered. And first must come iron.

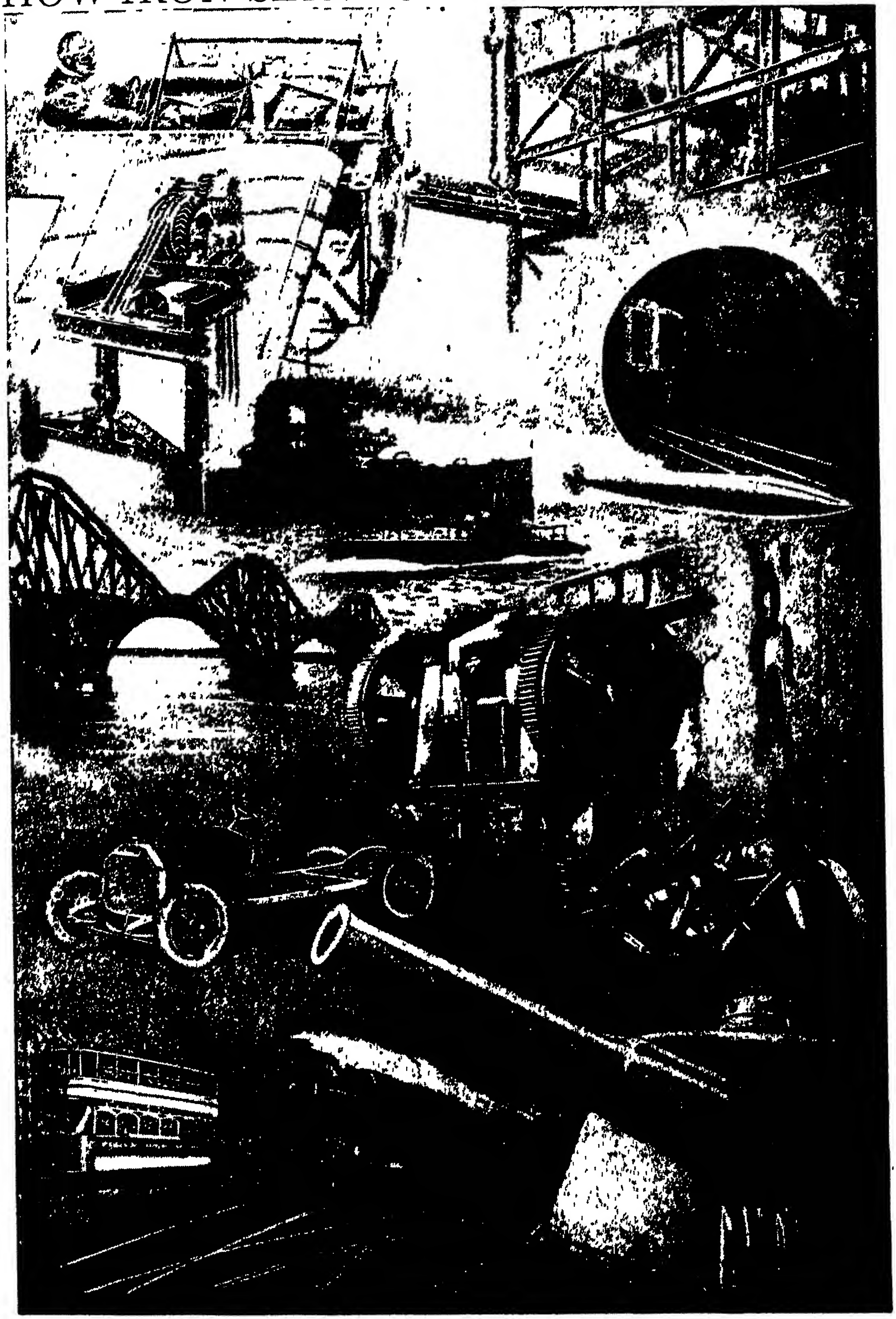
The Iron Age began in different countries at different times In Egypt, Chaldæa, Assyria, China, iron was used nearly six thousand years ago. In Etruria iron was known about 1400 B C, and in Gaul about six hundred years later. According to the poems of Homer the ancient Greeks used iron about 1200 B C In England the Iron Age began later still, but iron was worked by the ancient Britons before the invasion of Julius Cæsar. In Russia the Iron Age began only 1100 years ago.

The term "Iron Age" has a really deep significance; iron is the material foundation of the world's mechanical energies — its Atlantic liners, its airplanes, its automobiles and all its multifarious machinery. The great iron-masters are and must be the great world-masters; iron, cleared of dross and mixed with brains, is the great lever of the world.

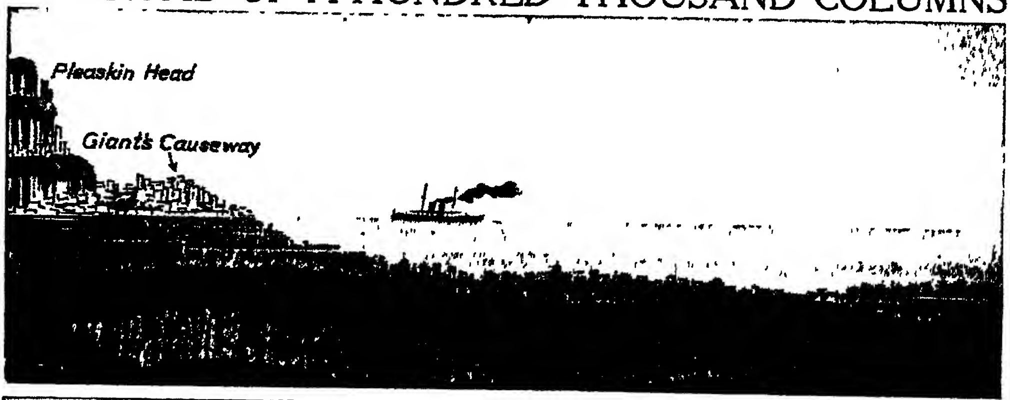
Without iron, civilization would be hardly possible. It owes its paramount importance to its unique versatility and adaptability — a versatility and adaptability rivaled by no other substance. Razors, nails, battleships, watch-springs, horseshoes, bridges, darning-needles, files, handcuffs, pokers, skyscrapers and a thousand other manufactured articles, testify to its divers uses. And the spear may readily be made a pruning-hook, and the sword may readily be beaten into a plowshare. It can be made hard or soft, strong or weak, brittle or plastic, fusible or infusible. The blacksmith in some countries tests the iron nails for his horse-shoes by bending them on his forehead, and yet iron projectiles can be made hard enough to pierce the thick armor of battleships, or smash hard ore, as one might sugar with a hammer.

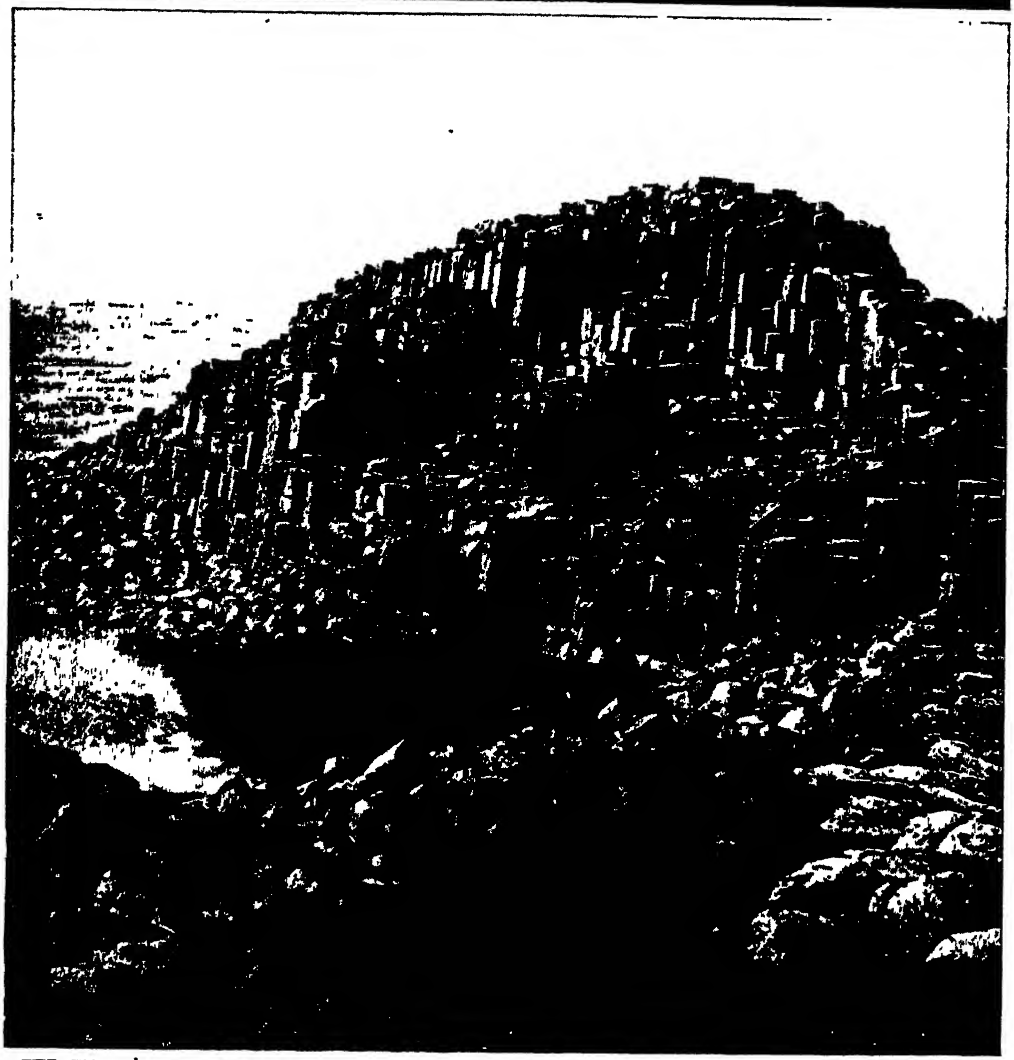
Strangely enough, the qualities of iron depend largely on the amount of foreign matter it contains and chiefly on the amount of carbon it holds, and all the resources of metallurgy have been devoted to combining the iron and carbon in right proportions. Iron is, of course, indispensable as the medium of mechanical activity. but it performs other functions in the world that must not be forgotten. Owing to its ductility and plasticity it forms a most serviceable medium for art.

HOW IRON SERVES THE NEEDS OF MEN



THE IMMENSE VARIETY OF NECESSARY THINGS FOR WHICH WE DEPEND UPON IRON AND STEEL

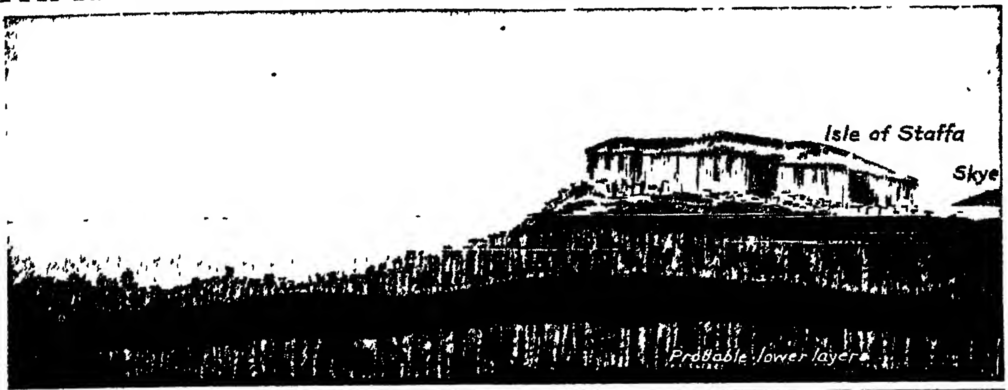


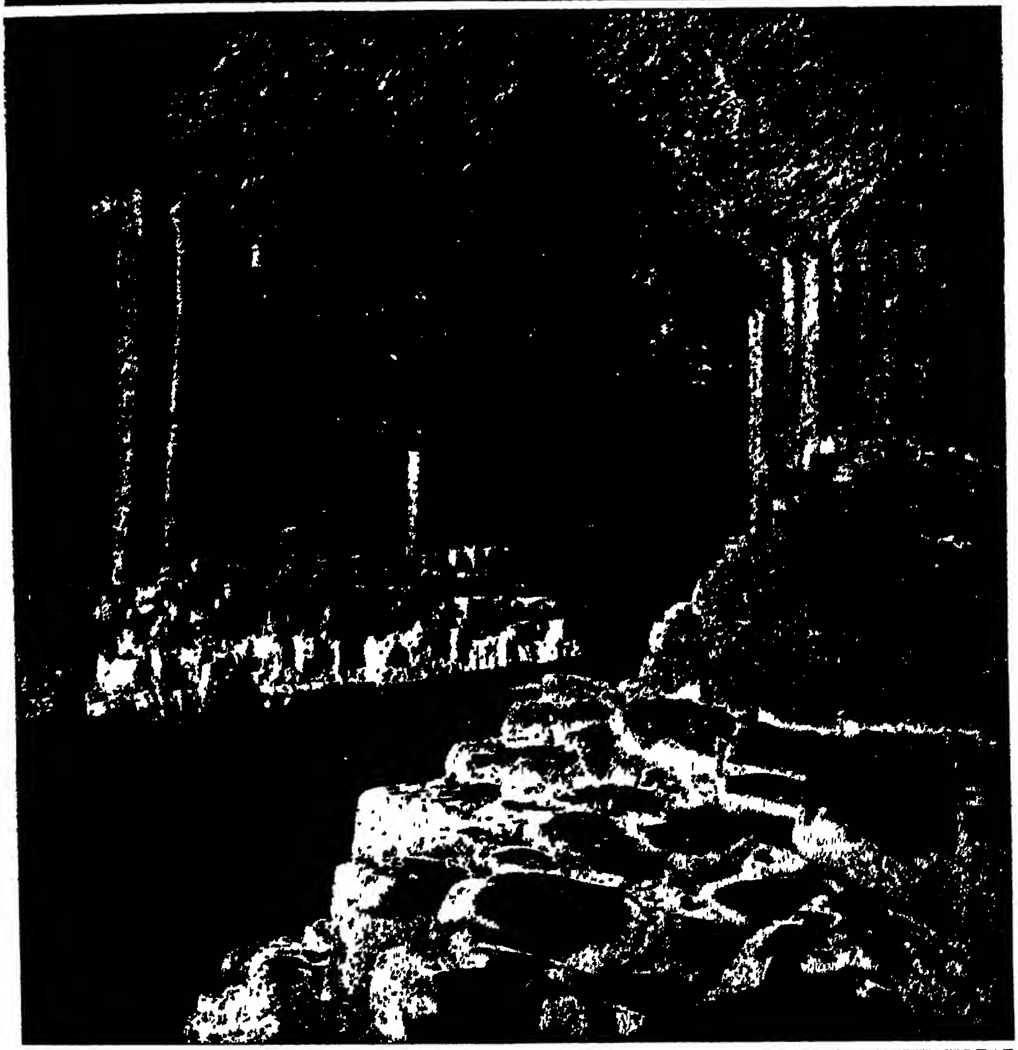


THE GIANTS' CAUSEWAY—THE EXTRAORDINARY GROUP OF BASALT COLUMNS AT ANTRIM, IRELAND

One of the most remarkable features of the crust of the earth in the British Isles is shown in these pictures. Popular legend has ascribed the stupendous formation of the Giants' Causeway to the labor of giants seeking to construct a roadway across the sea from Ireland to Scotland, where there is a similar formation at Fingal's Cave, in the island of Staffa. But this series of beautiful polygonal

THAT LEADS FROM IRELAND TO SCOTLAND





THE BEAUTIFUL CAVE IN THE ISLAND OF STAFFA, SCOTLAND, TO WHICH THE GIANTS' CAUSEWAY LEADS

columns owes its formation to the same great forces to which are due the transmutation of wood to coal, the crystallization of carbon in the form of diamonds, and the melting of rocks and their throwing up from the depths as lava or volcanic islands. The causeway is believed to have hundreds of thousands of columns of the oldest known rock, and to extend from Ireland to Scotland.

Admirably does John Ruskin put it in language which, though perhaps more eloquent than scientific, we may well be pardoned for quoting here:

> When you want tenacity, therefore, and involved form, take iron It is eminently made for that. It is the material given to the sculptor as the companion of marble, with a message, as plain as it can well be spoken, from the lips of the earth-mother. Here's for you to cut and here's for you to hammer Shape this, and twist that What is solid, simply carve out; what is thin and entangled, beat out. I give you all kinds of forms to be delighted in: fluttering leaves as well as fair bodies; twisted branches as well as open brows. The leaf and the branch you may beat and drag into their imagery; the body and brow you shall reverently touch into their imagery. And if you choose rightly and work rightly, what you do shall be safe afterwards. Your slender leaves shall not break off in my tenacious iron, though they may be rusted a little with an iron autumn.

Nor do the services of iron to art cease here. Iron gives much of its color to the world, making the soil umber. Iron is the basis of many colors, and without it the world would be anemic, a dirty white — "the white of thaw, with all the chill of snow in it, but none of its brightness." As Ruskin points out, it is the rusting of the iron, its oxidation, that renders it so useful for such purposes.

"The color that comes from the breathing of iron"

"We suppose it," he says, "to be a great defect in iron that it is subject to rust. But not at all. It is not a fault in the iron, but a virtue, to be so fond of getting rusted, for in that condition it fulfills its most important functions in the universe and most kindly duties to mankind. Nay, in a certain sense, and almost a literal one, we may say that iron rusted is living; but when pure or polished, dead."

The iron-rust is just iron plus moist air. The iron, as it were, breathes air as we do, "and as it breathes, softening from its merciless hardness, it falls into fruitful and beneficent dust, gathering itself again into the earths from which we feed and the stones with which we build, into the rocks that frame the mountains and the sands that bound the sea."

Agates, jaspers, cornelians, bloodstones, onyxes, cairngorms, chrysoprases, marble, porphyry, red granite, russet fields, red tiles, green moss, all owe their color largely to this wonderful rust of iron.

So much for iron. Let us look now at the very common metal aluminum, which we have already mentioned as forming eight per cent of the crust of the earth. Aluminum is as common as clay: the bricks and slates of our houses, the china of our dishes, are full of aluminum. But it required great skill to obtain it in a pure state, and only within the last few decades has it been possible to produce it cheaply.

The properties that give aluminum its very great industrial value

It is a soft, white metal like tin, and melts at 658° C. It is the third most malleable and most ductile of the metals; it cannot be beaten out so fine as gold nor drawn out so fine as platinum, but it can be beaten out into sheets of a 4000th part of an inch thick, and drawn out into wire one 250th part of an inch in diameter. It is also a good conductor of heat and electricity — such a good conductor of electricity that it often is employed for that purpose instead of copper. Its tensile strength is also great; weight for weight it is beaten in this respect only by the best cast steel.

In all these respects aluminum excels; but it owes its value to three other properties: it is not easily oxidized, it is not easily corroded by acids and it is very light. Since it is not easily oxidized, it does not rust away like iron in the presence of moisture and air; and since it is not easily corroded by acids, and is very light, it is obviously fitted for eating and cooking utensils, and is now largely used in the manufacture of such utensils. The uses of aluminum in our day are very numerous, and it is largely replacing brass and copper in many branches of industry. We will only mention here that it is now used in boat-building, in torpedo-boats, in fittings for ships instead of wood, and for making engines, automobiles, bicycles, tools, scientific instruments, airplane fittings, and that the range of its use is increasing.

The unique characteristic of metals which help forward human knowledge

Powdered aluminum burns vigorously, like magnesium, and a mixture of powdered aluminum and iron oxide, known as "thermit," burns so fiercely that if a little be ignited on an iron plate an inch thick it will burn a hole right through. Thermit is used in various welding operations.

Like iron, aluminum plays a part in the æsthetic side of life. If iron colors gems, it is aluminum that forms their basis. Corundums, sapphires, topazes, amethysts, rubies and many other precious stones are chiefly glorified aluminum-clay.

Another interesting metal with characters of its own is platinum. Platinum is a soft, white, lustrous metal found chiefly in Russia, now much used in jewelry. It is found almost pure, so no elaborate metallurgical operations are required to obtain it Nevertheless, unlike aluminum, its price has about quadrupled in the last thirty years. It is very malleable and ductile. Its melting-point is 1755° C. Like many other things, it owes its importance to certain almost unique properties it possesses. It is practically unoxidizable and it resists all acids except a mixture of nitric and hydrochloric acid, which slowly dissolves it. These properties make it *the* metal for chemical utensils and crucibles. It is used also for making stills for the concentration of sulphuric acid.

Platinum expands and contracts to heat and cold at the same rate

Liebig, the great German chemist, said that "without platinum crucibles, which share the infusibility of porcelain with the chemical inertness of gold ones, the composition of most of the minerals could not have been ascertained."

Platinum owes part of its value to the fortunate coincidence that it expands and contracts to heat and cold at the same rate as glass. It can therefore be used to penetrate the glass globe of electric lamps and support the incandescent filament. As the glass expands and contracts, the platinum does so equally, and thus the bulb remains air-tight.

Finally, we come to gold. Gold is found in many countries, and, being easily obtained and easily worked, it was one of the first metals to be used by man. The ancient Babylonians, Assyrians, Egyptians, Cretans, were all well acquainted with this precious metal, and it is very probable that in many countries gold was used for money long before silver or copper.

The beauty, the luster, the indestructibility of gold have at all times made it the symbol of desirability and the standard of value.

The gold that has drawn armed men from civilized lands into the wild

It has been one of the great motive powers of military conquest. It has been the lodestone and guiding star of many pioneers and explorers. And it has been a motive power, too, in chemical research, for nothing stimulated the chemical industry of the alchemists of the Middle Ages so much as the hope of discovering the Philosopher's Stone that would transmute all the baser metals to gold. Though they did not find the Philosopher's Stone, they found many other things.

Like platinum, gold is invulnerable to simple acids, except selenic acid, but is attacked by a mixture of hydrochloric and nitric acids and other mixtures liberating chlorine, iodine or bromine. It is naturally a soft metal, softer than silver, and almost as soft as lead, but if alloyed with a minute quantity of lead, cadmium or silver, it is rendered brittle. Its melting-point is 1063° C. It is very malleable and very ductile, it can be beaten into leaves 1/280,000th of an inch thick, and a single grain can be drawn out into a fine wire 500 feet long. Its malleability and ductility have rendered it suitable for fine ornamental work, and in days of pomp and pageantry gold textures have always been in evidence. The Assyrian kings wore robes interwoven with gold; the Egyptian mummies are often gilded with gold; Darius, the Persian king, wore a mantle with two gold hawks embroidered upon it. Even today, the more formal military and naval and ecclesiastic garments are embellished with gold braid.

The gold that was one of the very first metals ever found by man

But gold, now, is mainly the medium of mercantile exchange, it is less woven into kings' garments than stamped with kings' faces. It represents material wealth, and thousands of great iron crushers are thudding all over the world to get it out of the quartz and other rocks which contain it. Yet as a metal it is much less useful than iron or aluminum.

The geological distribution of gold is very interesting. It occurs both in alluvium — that is to say, in soil deposited by running water — and in rocks. When it occurs in alluvial deposits it is easily gathered as grains and nuggets, and no doubt in this form it was one of the first metals acquired by man. All that is required for this kind of gold-mining is just a spade to dig the soil, a trough with a current of running water to make mud of the soil, and a blanket to put along the floor of the trough to catch the heavy particles of the gold as they sink to the bottom of the stream. There are carvings in Upper Egypt, dating from about 2500 B.C., which show miners engaged in washing auriferous sand in hollowed-out stone basins, and melting the gold in primitive furnaces by means of mouth blow-pipes. In India, the El Dorado of the world until the discovery of America, sheepskins were often used to catch the particles of alluvial gold. Hence one of the explanations of the legend of Jason and the Golden Fleece. Even now the miners in the Caucasus put sheepskins in their sluice-boxes.

How gold exists in some form or other all the wide world over

Nowadays, however, washing of auriferous sand is usually carried out in a more scientific fashion. Mercury, which has a great affinity for gold, is often used to catch it, and there are various mechanical contrivances to facilitate washing.

Alluvial or "placer" diggings, as they are often called, are preëminently the poor man's opportunity; and all the great rushes to gold-fields have been to those of this description.

Not only has the miner a chance to make good by steady work, but any day he may find a nugget worth thousands The "Blanch Barkley," found in South Australia, weighed 146 pounds, the "Welcome," found in Victoria, weighed 183 pounds, and in California a nugget was found weighing 195 pounds. Placer deposits are found all over the world. In the United States, Alaska furnished 30 per cent and California 58 per cent of all the placer gold produced in 1921. California was responsible for 32 per cent of the entire gold produced in the United States, and of that 52 per cent was recovered from placer mining. About 53 per cent of the growing Alaska production is from placer mining.

One cannot mention gold without mentioning its young cousin silver, an ancient, ornamental and plutocratic metal But silver is not so ancient as gold, chiefly because it rarely occurs *native* in nature, but mostly in ores, from which it is difficult to extract.

Gold can be washed out of mud into a sheepskin or a blanket, but silver requires reef-mining machinery and metallurgical processes for its recovery.

Silver, gold's young plutocratic cousin — its beauties, uses, and whence it comes

Silver has a pure white color and a beautiful luster, and it has also a soft, plastic character that naturally lends itself to plastic art. It is second only to gold in malleability and ductility. Like gold, it does not tarnish on exposure to moisture and air; but, on the other hand, if the air contains sulphuretted hydrogen, a black film of sulphide of silver forms upon its surface. It resists the action of caustic alkalies, and is therefore used for making chemical vessels to contain caustic potash and soda. It is the best conductor of heat and electricity. Its melting-point is 961° C.

Owing to its softness, silver is not durable unless alloyed with a little copper. Silver is chiefly used for coins, table utensils and ornaments, but it is also used in photography. Like gold, it can be woven into cloth.

Mexico's rich mines have yielded more than one-third of the world's total silver. Until 1860 Bolivia, Peru and Chile were next in importance, but the remarkable development of silver mining in the western part of the United States after 1895 gave her a great lead over all other countries except Mexico, and indeed for a number of different years, her production actually exceeded that of Mexico. Silver-mining in the United States has, however, decreased greatly during the past decade and domestic production would now be comparatively small were it not for the very large amounts produced as a by-product in the mining of copper. It is estimated that fully three-fourths of our present production comes from this source. The Comstock, from 1859 to 1891, the greatest silver lode in the United States, if not in the world, is now insignificant in output.

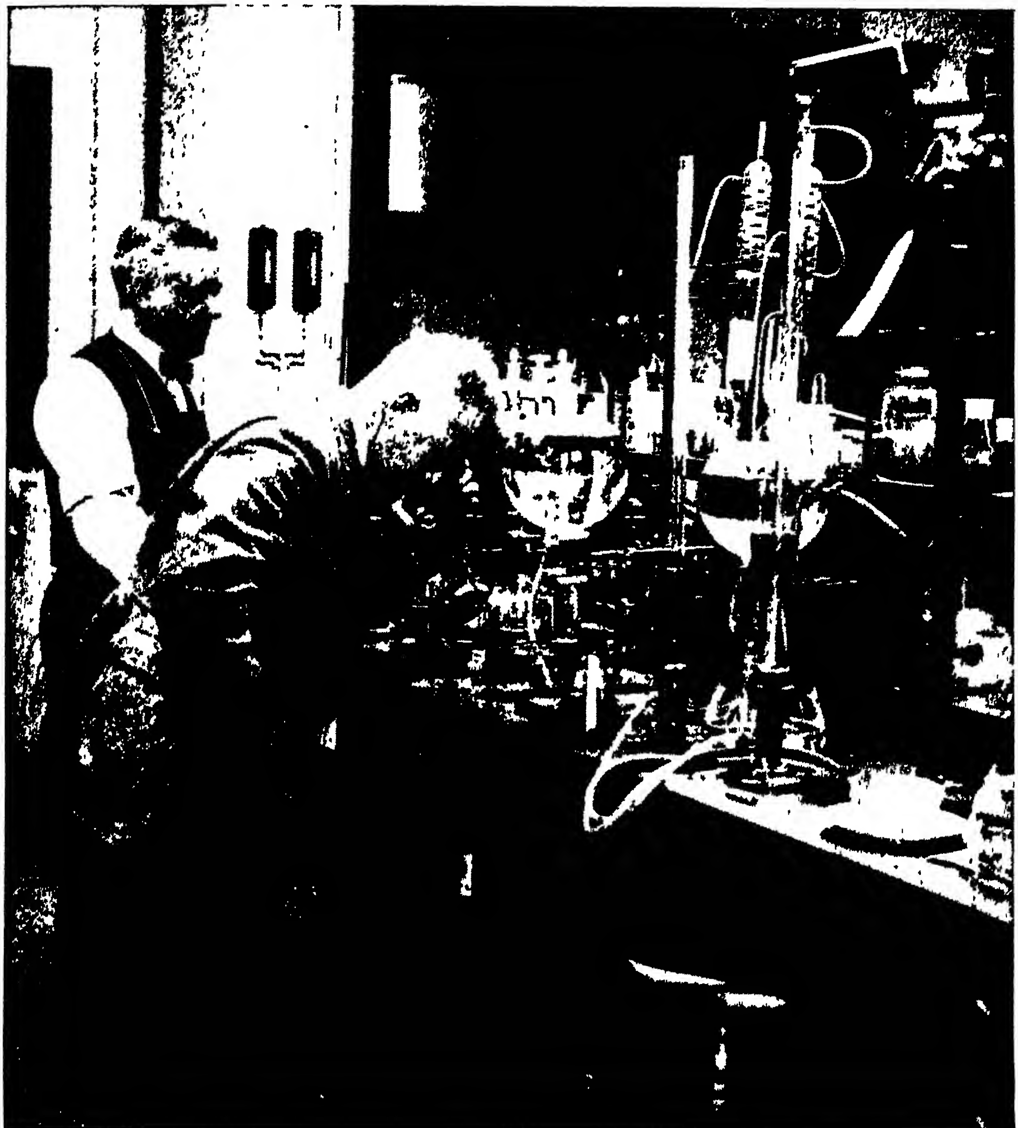


Photo Ewing Galloway, N Y

THE SUCCESSOR OF THE ALCHEMIST—FATHOMING THE SECRETS OF MATTER IN THE LABORATORY AT THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY

Silver output of the United States compared with Mexico and Canada

In 1920, the output for the United States was over 56,000,000 ounces as compared with 66,000,000 for Mexico and 13,000,000 for Canada, the latter country also showing a great decrease during the past ten years Montana and Utah now produce nearly half of the silver in the United States, largely from their great copper mines, with Idaho, Nevada, Arizona and Colorado following in production in the order named. Japan and Sweden are also large producers, and Uruguay mines as much as both of them together.

Silver naturally leads us to the consideration of quicksilver, or mercury, the remarkable metal which remains in a liquid state at ordinary temperatures, and solidifies only at $-39°$ C. It was a favorite metal of the alchemists, who, indeed, considered mercury and sulphur the father and mother of all elements. It occurs in nature chiefly in the form of the red sulphide called "cinnabar," and is easily separated from that sulphide in a pure state.

The metal which is a liquid at ordinary temperatures, a solid only at $-39°$ C.

Mercury readily forms alloys with other metals, and these alloys are usually named "amalgams." An amalgam of tin and mercury is used for silvering mirrors; amalgams of gold and silver are used for gilding and silvering; and amalgams of cadmium and copper are very much used in dentistry.

Due to the fact that it has good electrical conductivity, is very dense and is the only common metal which remains liquid at ordinary temperature, mercury finds an enormous variety of uses, especially in scientific work. Many important scientific experiments could never have been carried on without it. For example, while almost any liquid would do for a barometer, a light liquid like water would need a barometer tube about 35 feet long, instead of the 30 inches required for mercury. It is also used in thermometers, in medicine, and for many other purposes.

Mercury does not oxidize readily, but a red oxide can be formed This compound can easily be decomposed by heat, giving gaseous oxygen and pure mercury. A chance observation of this phenomenon by Priestly in 1774 led him to the discovery of oxygen, which was the beginning of the modern science of chemistry.

Lead is particularly notable for its heaviness, softness and its low melting-point. The latter leads to its extensive use in solders. It is also much used in storage batteries.

Tin and zinc are two metals whose principal value lies in their ability to resist corrosion Zinc is too brittle, and tin too soft and expensive for them to find a wide use by themselves, but they can both be plated over sheet iron to form the well-known tin-plated and galvanized iron wares, which partake of both the strength of the iron and the protective properties of the tin and zinc.

Copper was one of the first metals discovered by the ancients It was frequently used in coins and various ornaments Its reddish tinge when pure, and the golden color which it imparts to mixtures with other metals, makes it much used for ornamental ware even now. Brass and bronze fittings are now commonly used the whole world over.

Probably the greatest use for copper comes as a result of its high electrical conductivity combined with good tensile strength For wires of a given size, copper has the lowest resistance of any metal or alloy with the exception of silver, which is too expensive for ordinary uses. Copper is therefore used in millions of miles of wire for telephone and telegraph lines, and submarine cables. Copper combined with oxygen is also used to color glass red, making the so-called "ruby" glass.

This concludes the list of the most commonly used metals. The reader cannot have failed to note how each one has had one or two distinctive properties which made it desirable for certain uses. There is not a single metal which can be obtained in large quantities that does not have many uses for which it is superior to any of the other common metals.

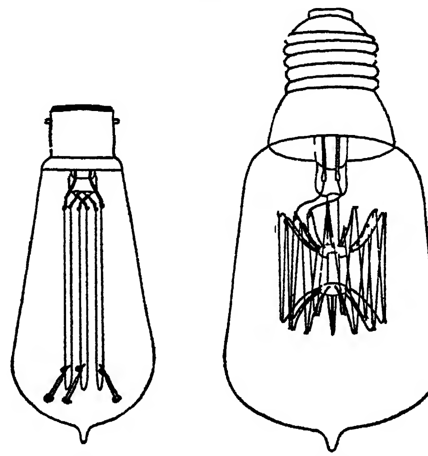
The industrial world not satisfied with the common metals

On the other hand, there are many properties or combinations of properties which are desirable and yet not furnished by any common metal or any mixture of common metals Moreover, the industrial world is extremely anxious to secure some metal a little stronger than wrought steel, a little harder than tool steel, of a little higher melting-point than platinum, a little less easily tarnished than silver. It is for a thousand such uses that the rarer elements become so extremely valuable in many cases. There are, in fact, several laboratories in the world which are making a systematic study of the properties of all the rare metals and their alloys, and these investigations have already yielded many valuable results.

Take, for example, one very limited field — the metals which are added to iron to give it more desirable properties The fact that iron is cheap and strong makes it by far the most widely used of any metal — and yet it has many faults and shortcomings. For machine parts it is not strong enough, and therefore small amounts of nickel, manganese, chromium or vanadium are added, which greatly increase its strength. For cutting tools it is too soft, and becomes too readily overheated, thus "losing its temper," and tungsten, chromium or uranium is added, which gives the modern high-speed cutting tools treated in another chapter.

In making castings and ingots iron is too prone to form blow holes and irregularities, and a small amount of manganese or titanium is added to prevent this. For chemical purposes iron is too readily corroded by acids, but the addition of several per cent of silicon makes an acid-proof metal. For many electrical purposes it is found desirable to add a small percentage of silicon or tungsten. To give iron or steel a bright, permanent finish it may be electroplated with nickel or cobalt. To make steel suitable for heavy armor plate for battleships, or armor-piercing projectiles for their guns, chromium and vanadium are usually added.

We see, therefore, that the addition of a small amount of any one of the above nine less common elements makes a steel which is far more valuable for certain purposes than the best of ordinary steels. This fact has greatly increased the number of elements for which the mining prospector must seek, and which the metallurgist must refine — and probably as much money is being made today mining elements which were practically unknown industrially forty or fifty years ago, as is made in the mining of gold or silver, to which so much romance is attached.



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THE OSMIUM LAMP THE TANTALUM LAMP

The large part played by the rare metals in developing the electric light

One purpose for which the rare metals have been thoroughly studied is to find which one has the highest melting-point, and hence could best be used in electric light filaments, for a lamp becomes much more efficient, and more like ordinary sunlight, the hotter its filament can be heated, and this upper limit of temperature depends chiefly on the melting-point of the filament. For a long time platinum was thought to have the highest melting-point of any metal — then osmium was found to melt higher, and many incandescent lights were made with osmium filaments. Tantalum next came to the fore, and for some time was hailed as the best possible solution of the lighting problem.

Then molybdenum was found to be still somewhat better, but before many of them were placed on the market, a way was found to make tungsten, the highest-melting of all elements, into fine, strong filaments, and the tungsten or "Mazda" lamp of today was produced. The efficiency of this type of lamp has already been made three times that of the old carbon lamps, and it will probably be perfected even further It is shown in our chapter on Electric Lighting in another section

One interesting use of a rare metal is in the so-called "pyro-phoric" alloys which are used in modern cigar lighters and other convenient appliances for lighting gas or combustible vapors. It is found that certain alloys of the rare element cerium, especially with iron, give off very hot sparks when rubbed across a rough metal surface, such as a file. Strange to say, this same metal cerium, united with a hundred times its weight of thorium, another rare element (both in their oxidized forms), is the basis of the ordinary gas mantle, which has prevented gas from being entirely replaced by electricity for lighting purposes.

A metal so extremely rare that it would be worth $40,000,000 a pound

And so the list might be extended almost indefinitely, for hardly a one of the fifty-odd known metals have had their properties thoroughly studied without finding new and important uses for them — so important that we often wonder how we ever did without them. Yet there are a score of metals about which little is known today, which will undoubtedly be considered indispensable in the near future. The field of the rare metals is one of the most fascinating now open to the investigator.

This account would not be complete without mentioning the one most valuable and most wonderful of all the rare metals, namely, radium. At present prices, a man who had a single pound of this rare substance could sell it for $40,000,000. But no one has ever been able to get more than a few grams, even by working over tons of ore.

The reason that radium has attracted so much attention is the fact that it is slowly decomposing into other elements, giving off heat, light and certain interesting "emanations" in the process. Until its discovery in 1896 chemists the world over had for a hundred years and more proclaimed the fundamental fact that one element could *not* be changed into any other. Much of the demand for radium comes from the fact that so many scientists wish to study it and the remarkable series of stages in its decomposition. Another important use for radium is in the treatment of cancer and various other diseases, where it has distinct healing power, though care must be taken that its powerful radiations do not injure the flesh. A piece much smaller than a pinhead carried in a bottle in one's pocket will in a few days produce a serious burn.

The amount of energy radiated by radium is surprising, especially when it is considered that the radium is practically unchanged in the process. Coal gives up a large amount of energy in burning, but once it is burned it disappears and can never be used again.

If a large ocean steamer burning 100 tons of coal a day could put a single lot of 100 tons of radium under her boilers, the heat given off would drive her across the ocean at the same rate, and then instead of having to coal up again, she could come back with the same lot of radium, crossing and recrossing a thousand times before it would be necessary to get more than a pound or two of fresh radium to replace the amount being used up.

Unfortunately the extreme rarity and high cost of radium will always prevent its being used in any such way as this. The fact, however, that one element breaks down and gives up so much energy, gives rise to the hope that the scientist may be able to make other more common elements break down in the same way, and thus draw upon the almost limitless stores of energy in the atoms themselves. If this can only be accomplished, the world will have little to fear from the exhaustion of its coal supply, or the gradual cooling of the sun.

THE UNFOLDING OF LIFE

The Tiny Cell which May Become an Oak or an Eagle, and the Astonishing Things We Know Concerning It

THE DEVELOPMENT AND GROWTH OF THINGS

WE know that there are living organisms which, from first to last, consist of only one cell; some of these are plants, and others animals. We know, also, that other living beings are colonies of cells, all descended from a single cell; and that this single cell and its descendants are in some cases plants and in others, animals.

We require to study the processes by which one cell may grow into an animal or another into a plant, and in either case into a member of a definite species — giraffe or whale, willow or oak, perhaps — but not a compromise between them. But, in the first place, we should be sure that we have clear ideas as to what we mean when we distinguish between plants and animals, just as we shall require distinct ideas — and more of them than our present knowledge suffices to supply — when we come to make the lesser distinctions between one species of animal or plant and another. In short. living beings all start from similar, though not the same, beginnings. They develop into evidently different creatures; and we cannot study their development without attempting to classify the amazing variety of forms in which we find that life embodies itself.

The first classification into plants and animals is the widest and deepest and most convincing, and that is what we shall deal with here, though we must never forget that the great principles of reproduction and sex, which we have studied, and the principles of development, which we are about to study, apply equally to the cell which will develop into an oak or the cell which will develop into a man. While we note distinction we must note similarity.

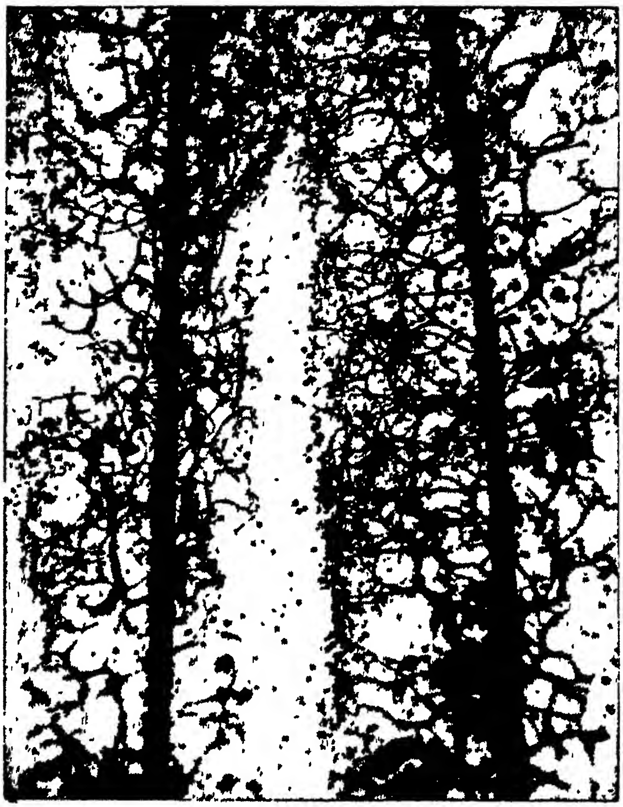
We have to admit that though the vegetable character of a forest, and the animal character of the tigers within it, are sufficiently contrasted — so much so that, in the past, vegetables have been but reluctantly credited with life at all — yet this evident contrast is less evident when we go back to beginnings. The statement is doubly true, and its double truth is to be noted, for each part of it supports and confirms the other, according to a great law of living nature — the law that the history of races, and the history of individuals, are similar in essentials. If we go back to the beginning of the tree or the tiger, the difference between them is incredibly diminished, for each began its existence as a single cell.

Thus when we studied sex and the nature of germ-cells, and the laws of their formation and union, and the evident consequence of those laws in the composition of the new generation, we had no need to say what species we were referring to. In truth, we were referring to big trees and big cats, to garden flowers and domestic "pussies" alike. The distinction between plant and animal, which is so tremendous in the adult, is not so evident in the earliest stages of the individual. It is the strict truth that we cannot, by a microscopic examination, distinguish between cells that will develop into creatures, animal and vegetable, which differ most palpably in their adult state.

This does not mean that the cells which have such a different destiny are the same, but it does indicate that the different branches and twigs of the tree of life may have started from a common stem — or at least it suggests some such idea to the mind.

The first students of these interesting matters were amazed at the suggestion which forced itself upon them — that this astounding resemblance in origin and principles of development, which they found between creatures far apart in the world of life, could scarcely consort with the idea of "special creation," and pointed to some community of origin, which we now express in the word "evolution." We are particularly to note the historical fact that the early study of development — that is to say, of individual development — could not but suggest a theory of the development of living species in general, which was later to receive the name of "evolution," and to make the greatest epoch in the history of scientific thought.

Long afterwards, we are now able, for purposes of comparison, to put side by side, as a matter of course, and with vastly extended knowledge, the development of the individual plant or animal from similar cells, and the development or evolution of races of plants and animals — nay, of all plants and all animals. And that is the comparison which allows us to assert a double truth in the statement that the contrast between tree and tiger diminishes if we go back to the beginnings.



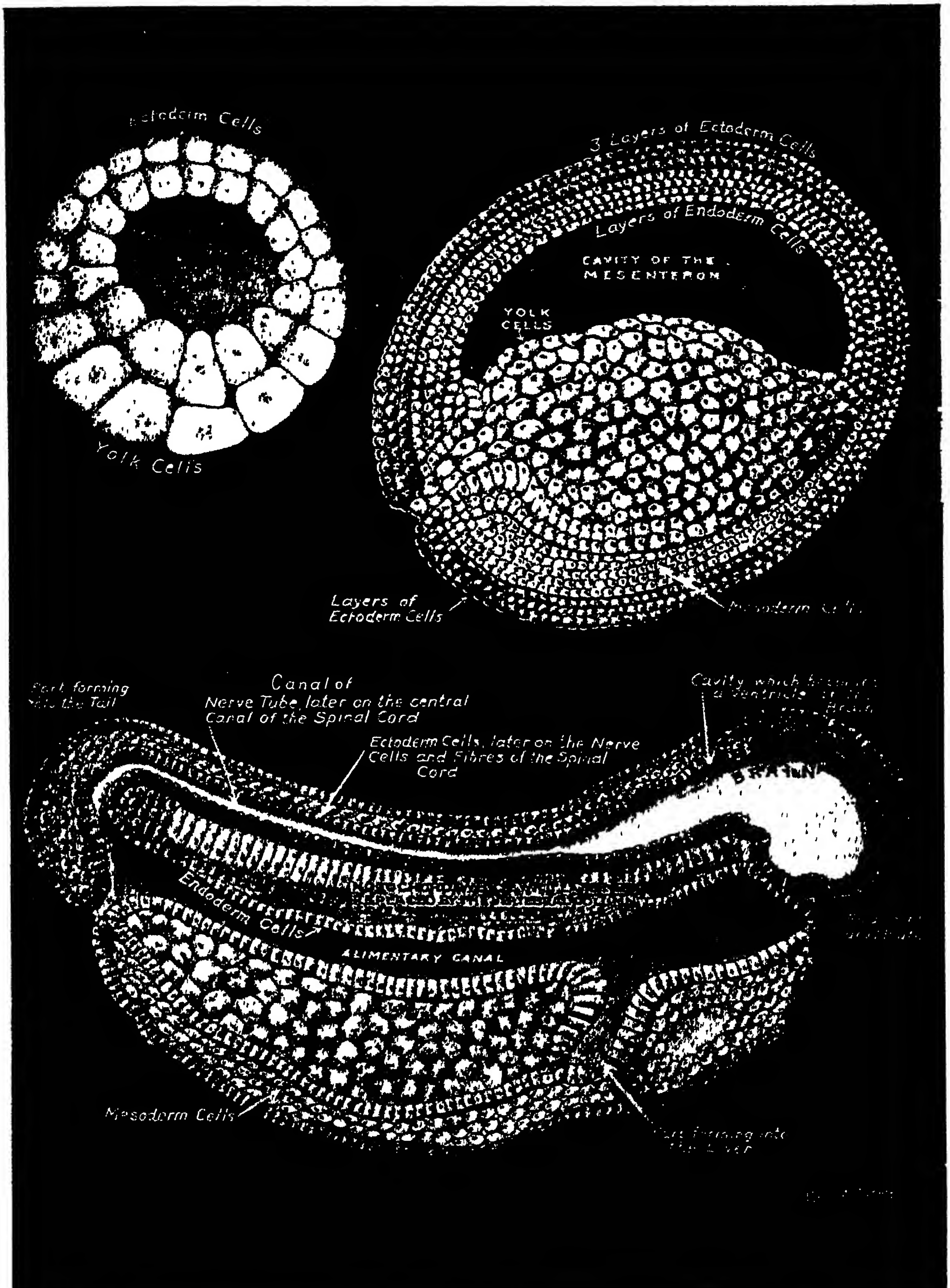
ON THE BORDERLAND BETWEEN THE VEGETABLE AND ANIMAL WORLD

This photograph shows a small piece of a fungus-like organism, called "mycetozoon" or "myxomycetes," which is found on rotten wood or decayed vegetation These organisms are interesting, because in the early stages of their life they have the characters of animals, while in the latter stages they display those of plants, so that they cannot be definitely classified either as animals or plants In the center the young organisms are seen freely moving away from the mother plants

When speculating or theorizing concerning the origin of living things, the usual way has been to speak of the V of life, having one limb for the plants and the other for the animals. But it is now assumed that the first forms of life, and many forms later than the first, were essentially vegetable, however simple and humble, for they must have lived as true plants do, by taking food from air and soil, without needing the prior activity of any other forms of life. Animals, as is well known, cannot feed in this way. They live, one and all, upon the bounty of vegetable life. The animal world is, so to speak, parasitic upon the vegetable; the fundamental distinction between them is found therein. It is true that some vegetables live as animals do, depending upon the products of past life, or upon the living bodies of other creatures, for their food, but they are the exceptions that prove the rule.

Life, then, may be represented by a rather lopsided Y, of which the primary trunk is vegetable, as well as the thicker and more direct of the two stems into which it is divided. At the point of division is placed a whole multitude of different forms of life, which have developed from the primitive vegetable character into forms that cannot definitely be called vegetable nor yet definitely animal.

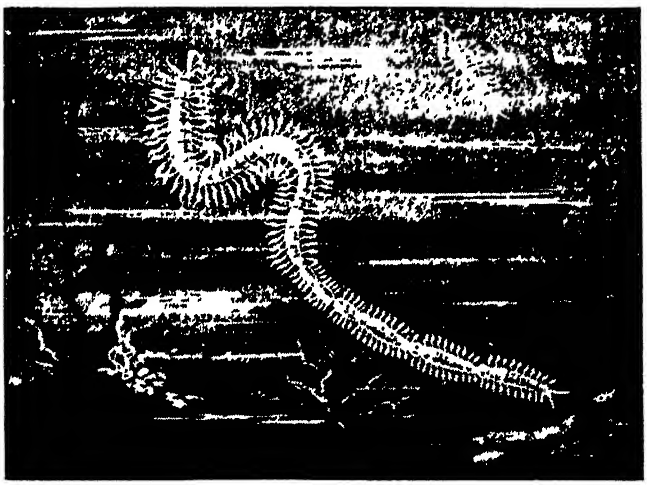
These "plant-animals," as they may on occasion be called, are of unique inter-



These pictures help us to understand the way in which living cells arrange themselves through the working of the mysterious forces of life into a complex organism. The artist has taken three stages in the early development of the embryo of a frog, beginning with the early cells, and showing how the three groups of cells — the ectoderm, mesoderm and endoderm cells — invariably produce certain specific parts of the organism. The drawing shows also how the brain, the spinal cord, the vertebræ and the alimentary canal are among the earliest parts to form, and it illustrates the way in which these simple cells group together, and form countless parts of any individual member of the animal world.

est to the biologist, for they must be the nearest modern and extant representatives of the forms of life from which the animal world is believed to have sprung,—forms of life which are vegetable, and yet are also animal, and which, therefore, from our former argument, we may look upon as, so to speak, plants which have gone part of the way towards becoming animals

These forms of life are neither numerous nor important, and we can understand why They have, so to speak, not made up their minds one way or the other; and accordingly they have been left behind in the race for life Definite plants and definite animals are more successful, because they are more decided, and have avoided falling between two stools The plants have gone their way, and the mighty animal kingdom has gone its way, immeasurably transcending the vegetable world, because through the animal world and its evolution consciousness and mind have been realized in the world.



A SEA-WORM AND ITS YOUNG

It is now admitted that variation, or the development of the various forms of life, both in animals and plants, depends upon the fundamental fact of sex The study of those species which reproduce sometimes sexually and sometimes asexually is, therefore, very important One of these species — the *myrianida*, a marine worm — is shown here, with several young that have been produced by budding attached to the end of its body. One has already broken away

As we travel further along the two limbs of the Y, the divergence between the two paths of life becomes more apparent — as in the case of the tree, which is a very high type of plant, and the tiger, which is a very high type of animal. It becomes very evident that the plants have staked their lives upon one principle in special, and the animals upon another, and that, the farther each goes, the more must they rely upon the principle which has already carried them so far.

The plant and the animal differ, most fundamentally, in the direction to which they turn their vital energy. Both sexes are found, of course, among both plants and animals, and the characteristic difference between them is observed in both cases, but the characteristic difference in vital intention is found, a thousandfold greater, to be the very difference between the vegetable and the animal kingdom. Just as we saw the female of any species, plant or animal, more conservative, more internally active, less externally active, more inclined to save than to spend, when contrasted with the male, which spends, struggles, strays, and is but little given to thrift — so do we find that the vegetable world constructs, builds up, stores, accumulates, lives in one place, and is thrifty, while the animal world spends its savings, roams, invents, and is never satisfied.

That is the essential relation between the two great branches of the living world; and as the two sexes are necessary for the future of the vast majority of species, animal or vegetable, so the two great branches, animal and vegetable, are naturally necessary for the future. Almost all plants could, indeed, survive in the absence of all forms of animal life, but no species of animal could long survive in the absence of all plant life. Again we observe the analogy: it has been said that life is essentially female, and it is also essentially vegetable.

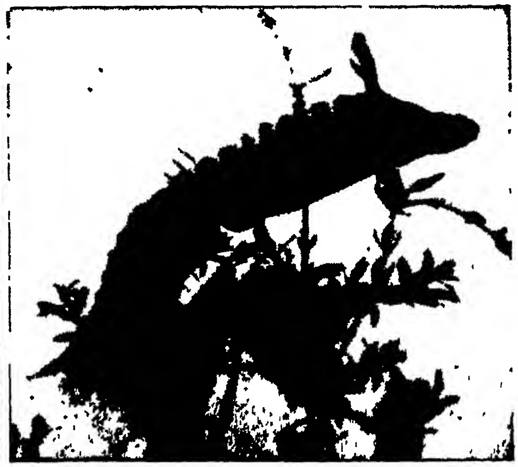
Animals as a whole are later in the sequence of development, and are essentially dependent; while plants as a whole precede and can maintain themselves alone. But for the highest evolution and ultimate purposes of life both animals and plants are necessary.

The variety of interplay between these great branches of the living world is endless and inexhaustible. We need only recall two salient illustrations — the formation by plants of chemical compounds which animals can consume, either directly, or tiger-wise by eating the eaters of the plants; and the formation by animals of carbonic acid gas, which they pour into the air, and which is a source of food for all the higher forms of plants. Thus plants serve animals; and animals, though absolutely dependent upon plants, do serve the higher forms of plant-life — to say nothing here of the part played by animals, especially insects, in the fertilization of plants

merged together — of the history of the race. We cannot usefully approach the problems of development, as we see them in plants and animals, nor can we appreciate the bearing of those problems upon the greater question of the origin of plants and animals and all their species, unless we take this key in our hands.

No doubt Von Baer's law has been worked to death; and the absurd straining of it, and the denial of facts which are inconvenient for it, have led many biologists to leave it on one side, but the evidence in support of it is so strong when we look at development as a whole, and it clears up so many of the difficulties encountered in the comparative study and

THE HALF-GROWN AIR-BREATHING STAGE OF MALE SMOOTH NEWT



FULL-GROWN MALE SMOOTH NEWT WITH FLOWING CREST DEVELOPED

Great though these differences be, the resemblance and fundamental identity of plants and animals is greater still. That is one of the lessons which the study of reproduction and of sex has taught us — perhaps the chief of its many lessons — for it demonstrates from a new viewpoint the unity of all life. And now we can define more precisely, and with a full appreciation of its scope, the great "law of recapitulation," which seems to lie at the base of individual development from germ to maturity This is the law, commonly named after the great biologist Von Baer, which asserts that the development of the individual is a recapitulation — in epitome, much abbreviated, and often with many stages omitted or

genealogy of different species, that we cannot do without it. Only we must not cling to dogmatic assertions founded upon it, which lead us into a cloud of words, and which, until the revelations of Mendelism within the last twenty years, had threatened to arrest the progress of biology, and to make the name of Darwin a stumbling-block instead of a clearing ax for progress.

That, unfortunately, is just what was done by the "neo-Darwinians," who were so concerned with the law of recapitulation, and the law of natural selection, that they were in danger of a title to the motto which is always a sentence of death to any school of thought: No New Truths Wanted.

The law of Von Baer simply asserts that the facts of individual development can best be explained, where otherwise they beggar the imagination and the reason, by assuming that they correspond to the evolution of the race to which the individual belongs. As has been wittily said, the individual, in the course of its development, climbs its own ancestral tree. This is the central principle of the science of development, of which the proper name is "embryology", and it is illustrated as well in the case of mankind as in any other species — better, indeed, for the process of development goes further, as the history to be recapitulated is longer

We find that the embryo of one of the higher animals, such as ourselves, is developed from a single cell, and is thus, at first, a one-celled creature We find, too, that at first its characteristics are quite as much vegetable as animal; later it develops gill-arches and other structures after the fashion of a fish; and only when it is born does it become an air-breathing animal.

Thus, the law of recapitulation is in general justified; and detailed study, alike of the higher animals or the higher plants, is rewarded by copious evidence of stages, in the course of their individual development, which resemble, in their sequence as in themselves, the probable stages in the long evolution of these types from lower forms. Innumerable peculiarities, not only in the immature but also in the adult individual, find here, and nowhere else, their explanation.

For instance, the human embryo at one stage has a trace of a tail; and the inconvenient fact that we are liable to choke, because our food and drink have to jump past the opening of the windpipe on their way to the gullet, is explained by the relative position in the fish of the gullet and the swim-bladder, which is homologous with the lungs of the air-breathing vertebrates. Here, and in countless other cases, the higher plants and animals, including men, may find "ancestral relics," and evidence of "the base degrees by which they did ascend."

How "like begets like" but never exactly

It was the law of Von Baer, together with the assertion and demonstration of this master embryologist that development proceeds from likeness of parts to difference of parts, which helped Herbert Spencer towards the enunciation of the law of universal evolution, and towards his invaluable study of the principles of life and its progress That is why we must have some appreciation of the facts of development before we can approach the principles of organic evolution and the origin of species

Let us now return to our starting-point, and look more closely at the amazing cell from which a perfect animal or plant is about to develop We can recognize the chief lines of its structure, but we cannot peer into the finer lines which make the detail and the difference, much less into the chemistry, which lies deeper still So far are we from seeing the adult being in the germ that, as a rule, we cannot distinguish the germ of one animal from another, or even that of a plant from that of an animal. Long ago, as time goes in the history of science, men thought that, for instance, the miniature chicken could be found in the fertilized egg of the hen, and there are even drawings extant which depict this little chicken as it was thought to be seen within the egg, under such lenses as were then available. Nothing of the sort is to be seen. Development is not an unfolding and magnification of a tiny model of the forthcoming being: it follows the lines suggested by Von Baer, and resembles one form of life at one time and a different form of life at another time.

Nevertheless, there is one way in which we can tell what a new nucleus, or germ, or zygote, will develop into — and that is by finding out where it came from. If it came from the union of gametes provided by a pair of fowls, it is uncommonly likely to turn out a chicken. "Like begets like," as the old saying goes. Somehow or other, in that indistinguishable cell, there lie the "promise and potency," the form and destiny, of an oak and nothing else, an elm, a fly, a horse, a human being, and nothing else.

SIX STAGES IN THE LIFE OF A NEWT

All animals at the beginning of their existence undergo rapid growth and considerable change of form and structure. During these changes the young organism is either contained in the body of the parent or lies in the egg, until it is able to lead an independent life. These pictures illustrate the various stages in the development of a newt. In the first we have the eggs of a newt attached to a water-plant; in the second and third we see the young newts taking shape within the eggs, in the fourth the newts have just emerged from the eggs; in the fifth they begin to develop their gills; and in the sixth picture we see the young newts six weeks old. (J. J. Ward)

The constant occurrence of variation in the infinitely small

That great fact is what we shall study more critically under the name of heredity. And one reason why more criticism is needed is that, though like begets like, it never begets exactly like. The offspring are not identical with either parent, and they are not identical with each other — except in the case of "identical twins," which are believed to arise from a single cell, and prove the rule, as we shall later see.

This difference, accompanying the likeness, is called "variation"; and our general survey of reproduction and of sex is incomplete unless we ask one further question: Is it the coöperation of the sexes that causes this variation? Do we find as much variation, or any, in the offspring of those species, animal or vegetable, in which sex does not exist? Evidently the answer to this question will be of enormous importance, in itself, and in its bearing upon the whole theory of evolution, for it will involve, in large measure, the answer to the general question: What causes variations? — and to the no less important question: What is the function of sex?

Now, we cannot doubt that variation occurs even in asexual reproduction, or reproduction "without sex." If we try to imagine how complicated the internal structure of even a microbe must be, we may well believe that in its most careful splitting to form two new microbes, not exactly the same quantity and quality of every constituent and structure shall be apportioned to both. But if the apportionment be not exact to the very uttermost, then each of the two new microbes, though in the main the same as its fellow and its parent, yet must differ from both; variation will have begun already. Plainly, therefore, it would be absurd to suggest that there could be no variation if it were not for sexual reproduction.

An excellent opportunity for deciding whether sex favors variation would appear to be furnished by those species which reproduce sometimes sexually and sometimes asexually.

The fallacy of study from one point of view without seeing all the facts

We can begin by studying the offspring of the one parent alone, and see how much they differ from their mother and each other; and we can then study the offspring where the female gametes have been yoked with male ones, and where, as we should expect, the offspring ought to differ more among themselves, and more from their parents, than in the former case.

This mode of inquiry, which seems so straightforward and satisfactory, has been adopted in the study of various bi-sexual species in which the females are capable of parthenogenesis, or reproduction without fertilization. Unfortunately, the work has been done from a purely mathematical point of view, by workers who were ignorant of the fatal fallacy which requires to be avoided at every step in all such inquiries as these. They noticed and measured differences in the offspring in the contrasted sets of cases, and assumed that these differences were really variations, due to original, native, inherent differences in the nuclei from which they were developed. But no one has any right to make any such assumption until he proves that what he is dealing with is not merely the difference due to different nurture.

The school that holds that variation does not depend upon sex

Plants that are essentially and germinally similar may exhibit all manner of differences, say, in longevity, to mention nothing else, according to whether they are watered or not watered, grown in soil or sand, in the sunlight or in a cellar. If we examine a number of specimens of any species, we thus find that they differ, partly because they are different from their very germ, and partly because no two of them have had exactly the same nurture, food, air, light, and so forth. The first kind of differences are true variations, and the second, of relatively trivial importance, are called "fluctuations." The "viometricians," or "measurers of life" (the immeasurable), ignored this vital distinction.

They found that certain differences between offspring were the same whether they were produced by one parent or by two — which we should expect, realizing that the differences in question were due to nurture and had nothing to do with parentage; and they concluded that it is impossible to accept the "view that one of the results produced by the differentiation of animals and plants into two sexes is an increase in the variability of their offspring" Thus, in the words of Prof. Karl Pearson, the most distinguished representative of this remarkable school: "Variability is not a product of bi-parental inheritance. Whatever be the physiological function of sex in evolution, it is not the production of greater variability."

The school that holds that the function of sex is the production of variations

Nearly all the students of this subject up to the end of the last century were led into following this view, little realizing what was the real nature of the material upon which such very erroneous conclusions were based.

No one who has acquainted himself with a single fact of Mendelism requires to be told that these conclusions are notoriously in contradiction with the exact evidence, daily more copious, which the present century has already gathered. Indeed, the rediscovery of Mendelism in 1900, and the work done since, restore biological thought, after an aberration which now seems incomprehensible even to those who shared it, to the position which the pioneer work of Weismann had indeed established, after Mendel's work was done, and before its rediscovery.

This honored veteran of biology, August Weismann, of Freiburg (1834–1914), lived to see his work, in its broad outlines, established more firmly than ever. He long ago maintained, as the result of his arduous and original research upon germ-cells and their behavior, that the most potent cause of variations in all living species except the very lowest is the intermixture of two somewhat dissimilar germ-plasms in the act of bi-parental or sexual reproduction.

The new lessons brought to us by the rediscovery of Mendelism

As the present writer stated it several years ago: "Each gamete *loses* half its chromosomes, and the new cell formed from the two thus contains only a portion of the (former) elements of each. The natural supposition was that there is a germinal selection of parental characters; some are taken, others left, and hence the new individual must vary from either of his parents, and need by no means necessarily strike an average between them. In other words, the function of sex is the production of variations; and the known facts seem to afford a ready explanation of the manner in which such variations arise."

As we now see, in the light of Mendelian experiments, it is the precise, particular, unique combination of character from the two parents that determines the character, often utterly new, of the offspring; and the facts known to Weismann forty years ago are multiplied and amplified manifold. We shall see elsewhere that this is far from being the only instance where men of science have been compelled, by the most recent work on Mendelian lines, to return to older views which the acceptance of "biometry" a decade ago seemed to have disproved.

The development of the various forms of life, of plants and animals in their great contrast, and of the various kinds of plants and of animals in their lesser contrast, is thus seen to depend all-importantly upon this fundamental fact of sex; and we are able to answer, with some certainty, and with far more evidence than was ever available before, the question of the function of sex. It is a twofold but single function. First, as we have seen, the function of sex is the division of labor, through the development of one individual into a male organism, with its peculiar powers, and of another into a female organism, with its peculiar powers. Each without the other is incomplete, as we suggest when we speak of a man's "better half." The life of the species is divided between them for its furtherance, and is entire in neither.

The union of two the true solution of the variations to follow

This division of labor serves the present, and it serves the future, for which the present, in the scheme of Life, always exists. The parental characteristics are coordinated in the care of the offspring — as when the mother nurses and the father provides. But this subdivision of labor, and this service of sex to the future, goes deeper still, for it is concerned with the construction of ever-varying types of creatures, some of which are an advance upon their parental and all remoter ancestors Thus evolution is made possible. The division of labor shows itself in the making of the new nucleus, which is half maternal, half paternal in origin, and which is therefore veritably new. Palpably asexual reproduction could not compare with such a process in the production of variations; and it is only one more example of the power of authority that the contrary view could have been successfully imposed, for however short a time, upon the minds of students.

Sex is thus "justified of her children" — *i.e.*, by her children; and the fundamental idea of the "physiological division of labor," which we owe to the French physiologist Henri Milne-Edwards, receives a further extension.

The details of individual development are thus reviewed with new eyes when we look upon the individual in question as a zygote, a double being, half paternal, half maternal, in origin and constitution; and we find, as is the glorious rule in science, that the old facts shine with a new light by reflection from the new ones. That is why embryology, the study of individual development, which seemed, only twenty years ago, to have become exhausted, has taken on a new lease of life, in the light of the new idea that each individual is at once old and new, one of a multitudinous species, and yet unique, because of its double origin in two cells — really two half-cells, for they have only half their essential substance — which have never met before, and will never meet again.

The details of embryology, as seen in this plant, this animal, or that, are innumerable. They have been most closely studied in familiar creatures such as the chick, and their principles are similar in widely contrasted forms of life The single cell of double origin itself divides into two — not the two whence it was fused, but a new two, each containing both paternal and maternal matter

What the study of embryology has revealed in the study of vertebrate life

These re-divide until, in typical cases, we find a ball of cells, a ball which grows and becomes a hollow sphere bounded by a single layer of cells This layer becomes double; and later a third layer appears between them. From without inwards the three layers are called "ectoderm," "mesoderm," "endoderm." In the case of the chick or any of the higher vertebrates, we can trace an orderly sequence in subsequent stages.

Thus the skin and the nervous system are always found to be developed from the ectoderm, the muscles, bones, and blood from the mesoderm, and the lining of the digestive tract, except just at its extremities, from the endoderm. Various names are given to the stages, as "*morula*," to that in which the young embryo consists of a ball of cells like a mulberry. Embryologists have devoted long years of labor to describing all the possible details in all manner of species; and the foregoing brief description outlines the gist of their findings, and indicates the point at which they had arrived, and where they themselves thought that they must remain until the new study of germ-cells and their formation and union began.

This new study involves a new embryology, which no more supersedes the old than the new astronomy or psychology supersedes the old, but which adds to and enhances and reconstructs the former knowledge. We learn that though we must distinguish between the essential facts of reproduction and those of development, yet the latter depends upon what the germ-cells have brought with them to be developed.

Why the offspring resembles the parents and yet is different from them

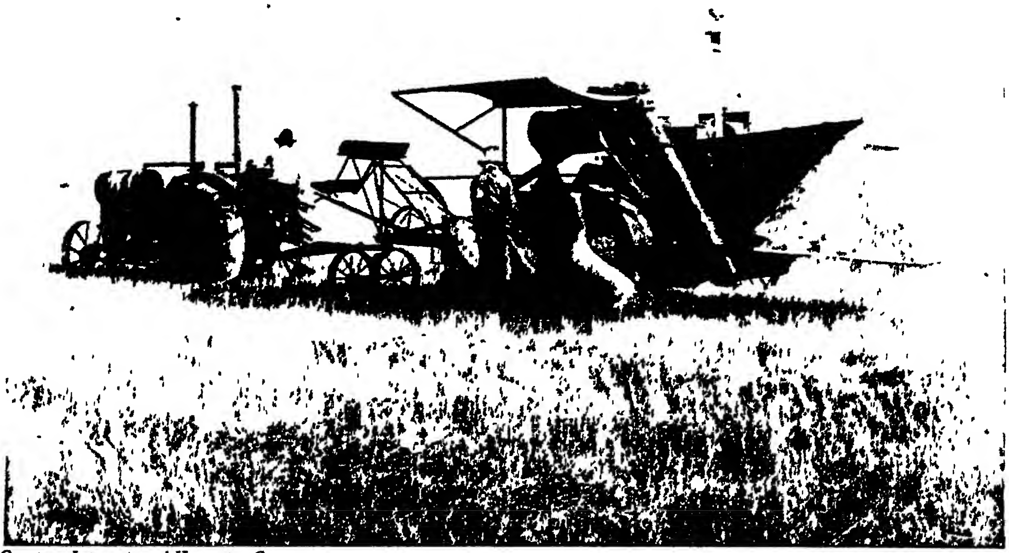
Embryology and heredity thus come close together; and we study development from our knowledge of the germ-cells, whereas formerly we could study it only from the point of view of the finished being, which was all we knew about. We see that the plant or the animal becomes what it is because it is the development of material of a special kind with a special origin.

We begin to see why the new creature resembles its parents, because it is developed from the same kind of germ-cells as they were; and yet also why it exhibits variation, and does not *exactly* resemble its parents — because it is developed from a unique combination of germ-cells, and therefore must be its original self, though it is still its "father's son" or "mother's daughter." This is often a hard lesson for human parents, but there it is.

In short, our successive study of reproduction, sex, and development has resulted in an appreciation of what is meant by variation, and of the orderliness and necessity and universality of variation, and even of the cause of variation, such as not even Darwin and Spencer were able to anticipate.

This is an advantage, as anyone may realize who reads Darwin's chapters on variation and remembers that Mendel's work was already published, and that Darwin lived and died without ever having heard of its existence; an unexampled episode in the history of science, which we must study elsewhere. Meanwhile we have the excellent fortune to approach the center and key position of our subject with definiteness of microscopic knowledge and experimental illustration, above all as regards reproduction, sex and development, which should help us incalculably to realize what is meant by organic evolution.

CHARLES DARWIN'S HOUSE AT DOWN, KENT, ENGLAND



Courtesy International Harvester Co

BRINGING THE THRESHER TO THE WHEAT

McCormick-Deering harvester-thresher which harvests, threshes and bags the wheat and blows the chaff away. Only two men are required to operate it.

Photo International Newsreel

BRINGING THE WHEAT TO THE THRESHER

A stationary thresher in the great Canadian wheatfields. The chaff is blown on to the pile through the siege-gun stack from which it is seen issuing; the wheat comes down the spout to the bags on the right.

SEED-TIME AND HARVEST

How Each Year's New Wealth of Wheat Keeps Sixteen Hundred Million People from Starvation

THE WILD UNUSED HARVESTS OF THE WORLD

BY far the most important event in the year in every part of the globe is the harvest; and it becomes of more importance every year as the number of people in the world increases. It is curious how few people understand this For the last fifty years the world has become more and more "urbanized"; that is, the minds of people are centered on the city and city things so that they look on life from a perverted and unnatural point of view. This urbanizing of people's minds has been observable in almost every country of Europe, and in certain sections of America. Happily "the new world has come in to redress the balance of the old," and there are parts of the world still — especially in the United States, Canada and Australia — where harvest is all in all.

In several parts of Europe that flocking of the people away from the harvest fields into the barren streets, a movement generally called the "rural exodus," is being arrested. In Denmark, where the government has done more for agriculture than any country has ever done, people have gone back from the towns to the harvest fields. This means that seed-time and harvest are beginning to take their proper place again in the world.

They matter supremely. Should one year's harvest fail we should all be on the edge of starvation almost instantly. In England this appalling prospect is more real than in any other country, because England grows less food in proportion to her population. But everywhere man lives only on sufferance of the farmers, who are the world's rulers.

Very few people realize how vast and how vital harvest is. Even in England, whose wealth is supposed to and does come, in great part, from her ships and her coal, the greatest wealth is still derived from her harvests of food for man and beast. We think of the United States as a country to which the oil fields and mines bring inexhaustible wealth, but oil and coal and gold are hardly worth considering in comparison with the harvest. It is a striking idea that one year's harvest brings enough gold to build and equip all the great railways with their thousands of miles of rails and their tens of thousands of cars and engines and rolling-stock.

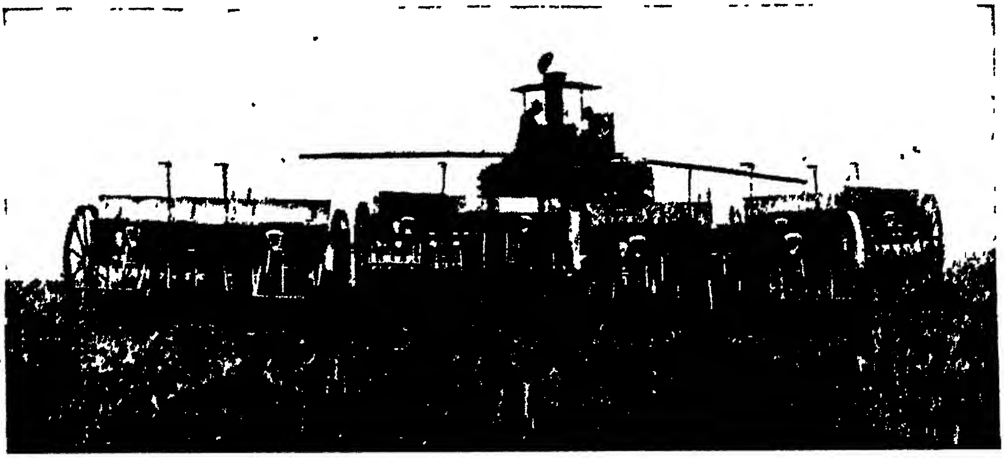
The mere figures of some few of the crops are enough to fill the imagination. The corn crop of the United States averages almost 3,000,000,000 bushels a year. The oat harvest comes to 1,300,000,000 and the wheat harvest 750,000,000. The corn crop exeeds a billion and a half dollars a year, while the wheat crop is occasionally worth a billion dollars. The grain crops in all probability exceed four billion dollars a year in value; but, in spite of this fact, population is so rapidly increasing that soon almost none of this will be exported, or become available for countries which do not grow enough for themselves. It is calculated that in all 1,600,000,000 people in the world largely depend on the wheat harvest for life. It can then scarcely be denied that harvest is the most important event of the year, and every nation should put forth its energy to make this great and glorious.

The governments of the world have generally been slow to recognize the importance of taking steps to directly improve the harvests In the United States the first great step was taken in 1862, when means were provided by the federal government for establishing state agricultural colleges Within a few years an agricultural college had been provided for every state. These still receive support from the government, but principally by each respective state In addition each state has an experiment station that conducts experiments and publishes bulletins of information regarding the best methods of farming. There is also the great national Department of Agriculture at Washington, which publishes bulletins and assists farmers in all possible ways.

When all this is done the many workmen may return to the cities, the machines be set aside in shelter, and nature left for the rest of the year to bring the seed to perfection.

It is worth while to remember in its various steps the process of harvest. The handful of laborers left on the great farm during the whole year are joined at the end of July, or about then, by the imported harvesters. Perhaps 200 of these men arrive on a 10,000-acre farm, along with a trainload of machines, at the end of July. As far as the eye can see the level plain is golden with grain across which you can see a puff of wind travel as you can trace it over the sea.

"Upon the great fertile plains such as are those of the Pacific Northwest, an enormous harvester is used which has a cutting line 52 feet wide. These machines cut, thresh and sack the grain at the rate of 1600 sacks a day, and cover an area in that time of 100 acres.



A GASOLINE TRACTOR DRAWING FOUR DRILLS FOR SOWING SEED IN THE WHEAT BELT

To understand the meaning and magnitude of harvest it is necessary to come to the United States or go to Argentina or one of the newer countries, though harvest is wonderful enough in Egypt and in India, while in the wheat belt of North America the whole energy of the country seems to mount to a sort of rage at harvest time. Workmen pour out of the cities to the great farms. Millions of dollars are spent every year for harvesting machinery. The whole great business is condensed into the shortest possible period and nature has so arranged that this space may be very short indeed. Consecutive months of the year happen to be equally suitable for harvesting, plowing, cultivating and sowing.

"Where self-binders are used the bonanza farmer expects one machine to cut at least 200 acres, and three men are required for each of them. The harvest lasts from ten days to three weeks according to the weather."

As soon as all the wheat has stood long enough in shocks in the field to thoroughly mature, it is hurried to the great threshers, and from that moment is dealt with only by machinery, till it is made up in retail amounts of flour.

When the grain has gone away by rail or on the vast lake steamers, a great bonfire is made of the straw, and a week or two later the plows are on the land, and then the harrows, and then the drills dropping rather more than a bushel to the acre. On a good farm so much seed should produce about twenty-fold, so bountiful is nature. It produces very much more where the farms are small and much care given

It is both an interesting and important query how far the harvest of each acre may be increased by artificial aid, both in respect of cultivation and in improving the plants. The question of harvest always suggests wheat and yet, of course, there is no real reason why wheat should take so prominent a place. Thus potatoes, for example, produce starch just as wheat does; and man can make flour even from bananas. But practically nothing has been found equal to wheat. It yields a large crop of food which is, unlike the potato, very free from moisture, and is therefore condensed. It is not very liable to disease, does not exhaust the ground overmuch and is easily harvested.

It is believed that wheat has been cultivated from the earliest ages in the history of mankind. But without going back to the Stone Age, of which we have little more record than that of the rocks, we know quite certainly that wheat was cultivated in Egypt before the Pyramids were built, and in Asia Minor before the Trojan wars and the mythical yet dimly historical days when Hector and Achilles fought and Ulysses wandered over the seas. It seems likely that farmers found the wild wheat plant on the slopes of the Caucasus, or on the plains of Mesopotamia, and, cultivating it on the plains which the Tigris and Euphrates rivers endow with permanent fertility, produced the seed which now gives life to the greater part of the world.

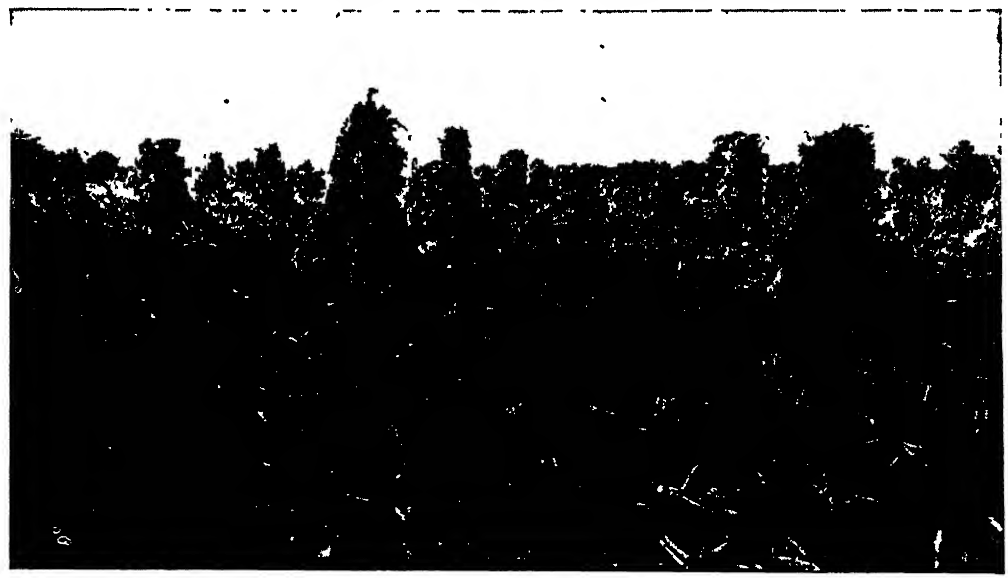
IN THE MAGNIFICENT WHEAT-FIELDS OF TRAMPING LAKE DISTRICT, CANADA

Even rice is giving way to wheat. For centuries rice has been the chief harvest of the Japanese, and they have performed one of the miracles of the world in the way of intensive or close cultivation of the crop. They set out each plant separately in the field, and by their system of transplantation get such crops as western farmers would think incredible.

But as greater wealth has come to the people of Japan they have begun to prefer wheat to rice; and it seems an almost universal instinct in man to desire a wheat harvest if he can grow it. It is with the Japanese in their island today as it was with the English in their island when the forests were cleared away, and Alfred the Great issued the first agricultural pamphlet known in our history. Wheat, indeed, is the world's harvest.

The plant will grow in as great a variety of soils and climates as any useful plant. There are many places, no doubt — Newfoundland is one — where oats will ripen and wheat will not, but the range of wheat is very great, and the wheat grain is, of course, much richer in food. It is the custom of civilized nations to reject all but the starchy portion of the grain, about 70 per cent. The poor of Europe are in the habit of regarding this pure white flour as the finest and most delicate of foods. It is a most happy fact in nature that this great food-giving plant will grow up in northern regions, as high as the 69th latitude in Norway, and hundreds of miles further north in Canada than used to be thought possible. It will flourish over 4000 feet high on southern mountains, and in some respects surpass in that rarefied air the great crops of the fertile plains.

The question arises whether after all these numerous centuries we can improve this harvest as the Babylonian farmers — if that theory be true — improved it after the first discovery. Many examples might be cited to show how crops can be increased by introduction of better varieties. The introduction of Turkey Red wheat from Russia into the great winter wheat belt west of the Missouri River has made possible the profitable culture of winter wheat from Texas to South Dakota, a region where the older varieties were very uncertain. Macaroni wheat was introduced about 1900 from southern Russia into the Dakotas. It is quite resistant to the rust disease of wheat and also endures dry, hot weather, and is more productive than any other spring-sown wheat in certain sections of the Dakotas. You can grow this short in the straw, so that wind and storm will not flatten it; you can also grow it with small "berries" or big; with grain of high quality and lower yield, or high yield and softer quality; and you can buy it for sowing in the autumn or for sowing in the spring. Each year multitudes of experiments are being made by men of science all over the world, and they promise great improvements. Some years ago a professor of an agricultural college got together a collection of the world's wheats,



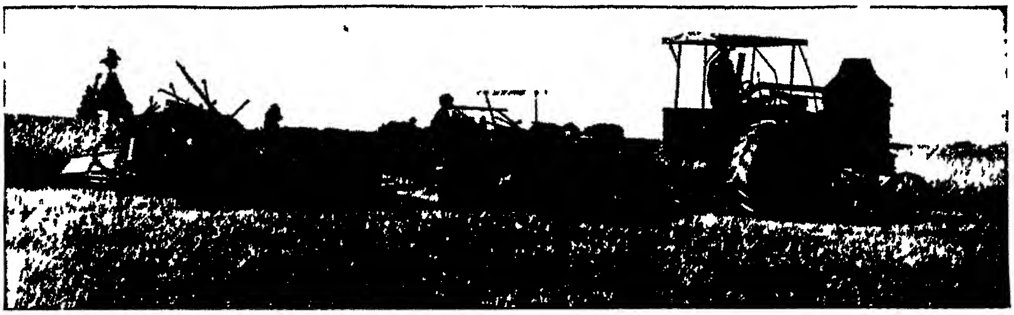
CORN IN SHOCK IN ONTARIO

what may be called the more or less "original wheats." From this outfit he selected the two hundred best, and then the fifty best, and from these he grew the picked seeds It is his opinion that from this collection of his he can produce at any time a wheat which shall have the best that any man of science can "create" by breeding. He has bearded wheats, red wheats and white wheats, and strong wheats, even so-called "mummy" wheats in which the ears are branched. It is possible that his claim is true.

Many plants have a tendency to grow smaller; and these cultivated plants which have been swollen beyond all comparison with the plants from which they originally sprang, relapse into smallness very rapidly If you leave a pansy to seed itself in a field it will become very small and the same in color and size as the wild violet within three or four years, perhaps within one. We have, therefore, to work well in order to keep our harvests up to their present level, as well as to improve them yet further. But this improvement is going on There has been more advance made in increasing harvests during the last generation or so than had been made perhaps for thousands of years previously.

We have been talking principally of wheat, but the improvement is yet greater in other plants, especially those grown in market gardens and in private gardens. But how the vegetables and grains are improved in size and quality will need a special discussion of its own. It has been shown how harvest on the great plains of North America is condensed into the autumn, and the energy of nature and the energy of workers are concentrated into harvesting through August, September and October, when the grain is cut, threshed, and shipped, and the ground cultivated and the seed sown, so that for nine months of the year a few men only are needed to watch the progress. This is the case in most of the great "granaries" of the world — in Siberia, as in America — though in the more northerly areas of the more severe climates the autumn work of the American bonanza farmer is postponed to the spring, lest the winter, as sometimes happens, should kill the young plants and the frost attack them before they were protected by the kindly snow.

But in Europe, harvest — if the word be used in its wide sense — is not a quick and sudden event of this sort; and as the farmer's skill grows, and the need of making the fullest use of the ground increases, the period of harvest is drawn out into much greater length, the ground becomes a sort of factory in which the hands are almost always busy and any slack time is deplored. Some very remarkable examples of the method of keeping the factory of the ground in motion may be seen in New Jersey, where farmers are able to grow two crops of potatoes off the same ground, one of early and one of late potatoes. Gardeners have long been used to work their ground in this way, but it is newer with farmers; and perhaps some day, as the ground becomes more and more valuable, the farmer will become more and more of a gardener. In Florida the first potato harvest is gathered in the spring of the year, harvest progressing northward, the Maine crop being harvested in November.



A GASOLINE TRACTION ENGINE DRAWING TWO REAPING AND BINDING MACHINES

Again, the system of what is called "catch-cropping" is increasing in favor every year. By a catch-crop is meant a crop which, as it were, steals a part of the year. For example, when a farmer has harvested his early potatoes, he may sow rape-seed, which will give him a second harvest within the year in the shape of green food for his animals.

It has been said that man has always to work to prevent the harvests relapsing and the cultivated plants returning to their wild state. He has also to strive against the inroads of weeds upon all cultivated land. The farmers of the United States and Canada in the last few years have been forced to use special machinery to sift from the wheat weed seeds that were at first unknown. But in considering the wonder of the harvest one has also to look at weeds as an example of the astounding fecundity of nature. Many of the weeds are very little less valuable than the harvests which have now supplanted them. Watch a Shetland pony eating rough hay. You will see him pick out first the nettles. Is there any plant which is generally regarded as a more noxious or useless weed? Some of the weeds would be well worth cultivating, and agricultural reformers have recommended their growth as a regular harvest. Such weeds are hogweed and comfrey, both of which would yield a very heavy weight of harvest. But the energies of men are not exerted with half the earnestness in adopting plant life as in securing mechanical power.

Indeed, harvests are all about us, the hazels, the briars, the thorns, the trees and the grasses giving harvests of fruit and leaf and stem and root. Science has selected the best of these — that is, those best suited to the needs of man — and nature has pointed out the way how to guide them to yield the greatest value.

The way of a seed in the ground is at least as miraculous as any of Solomon's four wonders; and if we could understand the progress of one such wheat seed of the million sown it would give us as much knowledge as Tennyson suspected to lie in the "little flower in the crannied wall." There is not, perhaps, a great deal which is wonderful in the greater part of the seed as we see it with our eyes, for the bulk of it is pure food. In a wheat seed or a bean — which are in structure and in their classification as different as two seeds could be — the bulk is food for the coming plant.

A wheat grain is for the most part starch, which lies as a storehouse for the plant just in the same way as the honey-bread and pollen that are buried by the single bee along with the egg. To see in the late spring the young bees coming up out of the ground is indeed almost an exact parallel to the coming up of the blade of wheat. Both are buried, both are provided with a store of food, both devour the food as they develop; and, when they have so obtained strength, both use it to thrust themselves out of the ground. There, of course, the parallel ceases.

MCCORMICK-DEERING HARVESTER-THRESHERS IN OPERATION IN THE WEST

THE ASTONISHING GIANTS

The Life and Characteristics of the Elephant, the Rhinoceros, the Hippopotamus and Giraffe

SURVIVALS OF THE AGE OF MONSTERS

THE elephant, the rhinoceros, the hippopotamus and one or two other weird-looking survivors from past ages help us to believe the almost incredible record of the rocks Without these mighty beasts as evidence of the prodigal hand with which nature piles bulk on bulk and adds strength to strength, we might hesitate to believe the story of the giants with which the earth in its twilight was peopled. But these colossal mammals are all unwittingly recorders, animate analogies, whose suggestive testimony is not to be overlooked.

In the twentieth century Asia and Africa possess animals strangely fantastic in design and unwieldy in bulk like those of distant ages. They enable us in imagination to clothe with flesh and invest with action and intelligence the mighty bones which we blast or dig from the stony matrix in which they were interred long before the coming of man

The elephant remains the most impressive picture in the whole animal kingdom. He has about him a suggestion of the archaic; and as he stands, quiet and reflective, at his ease, he suggests some mighty figure carved from a rock rather than a thing of flesh and blood. The elephant is one of the rare instances in nature in which development of bulk has been accompanied by development of brain. It is to that phenomenon that we owe the persistence of the species. On the other hand, the rhinoceros and the hippopotamus have survived without high mental development, and the same holds good of puny insectivorous animals, and of degenerate types such as the sloths.

But there is a great difference between elephants and the other ungulates on the one hand, and the more primitive types on the other. The hippopotamus and the rhinoceros have been favored by their surroundings They have not had to endure excessive competition. The insectivores have adapted themselves, in common with other animals of lowly type, to life underground or in the trees, or to night prowling in search of food easily obtained without fighting other animals.

But the elephant is not fitted for a semi-aquatic life such as that which the hippopotamus leads; it cannot burrow like the animals that make their home underground; it cannot take to the trees. It has had to make the best of life in the open or in the jungle. The fact that in past ages it spread far and wide over the earth shows that adaptability was not lacking in the early elephant forms. The mammoth, which was a cousin of the Indian elephant, roamed from England to Behring Strait, whence it penetrated into America. It was woolly and hairy, and thus suited to the cold climates which it inhabited. It was contemporary with primeval man; its flesh helped to feed him; its hide made him such harness as he employed; its ivory was his drawing-board, and we owe to the sketches on mammoth tusks our knowledge that he and the mammoth were rivals for the earth.

Geologically speaking, the mammoth ceased to exist but yesterday. Entire carcasses have been found embedded in the soil of Siberia and Russia, an exceptional thaw melting the frozen mud in which they had been for ages enveloped.

Dean Buckland made his guests partake of flesh from a mammoth which came to light in his day, redeemed from the marsh in which it had been frozen after sinking hundreds of thousands of years before A century ago one was discovered near the mouth of the Lena, entire, with its brain uninjured, its eyes still staring from the head, with flesh and hair and internal organs intact, with its last meal of young shoots of pine and fir and cones undigested in its stomach Siberia is a mortuary of mammoths, and has exported enormous quantities of ivory derived from this source. Indeed, it has been stated that certain islands of Siberia are simply heaps of mammoth bones.

The dwindling in size of the elephant family when they are ill fed

The mammoth, the mastodon and the dinotherium were the commonest of the varieties into which the elephant family developed, but today only the African and Indian elephants remain. Mammoths measuring 13 feet in height have been found, but the average seems to have been about 10 feet, a good deal smaller than that of present-day elephants. Hence the mammoth was of slighter proportions than some members of the elephant group which have existed. The Narbadda elephant of India, for example, is known to have measured at least 16 feet in height, which is quite 4 feet more than the largest known modern elephants. But there were many sizes of proboscideans, from the Narbadda giants down to pygmy elephants, no bigger than Shetland ponies, which frequented Malta, Cyprus and some of the neighboring islands in pleistocene times. Both mammoth and mastodon were common in North America, too, in those days, and their skeletons are mounted in American museums It is difficult to account for the disappearance of the mammoth and the mastodon, seeing that such magnificent animals have survived in Africa and Asia. Change of climate, we must suppose, was primarily responsible. But the Indian elephant, like the tiger, seems to have descended from stock which had become habituated to a cold temperature.

Is the elephant most at home in hot or in cold countries?

Young Indian elephants are born thickly covered with hair, as were the mammoths, and the species is very intolerant of heat, seeking shelter throughout the hottest part of the day, and taking baths to cool itself, and even adding to its defense against the sun an artificial thatch for its back The African elephant, on the contrary, appears to revel in the heat of a tropical sun, and is active throughout the day.

It is not impossible that disease resulting from parasitic organisms had something to do with the disappearance of the mighty hosts of trunk-bearing animals which once roamed the earth. The human race is smitten from time to time by plagues which sleep for hundreds of years; and it is not unreasonable to suppose that the disappearance of so many of the great animals of the past may have been due in some measure to a corresponding cause.

Be that as it may, the tuskers of India and Africa remain to remind us that not all of nature's wonders are extinct. The boast would not hold good for long — at any rate, so far as Africa is concerned — were it not for legislative action. The slaughter of African elephants has been one of the scandals of latter-day civilization. For years the ivory imported into Belgium represented the destruction of 18,000 elephants a year. The death-roll was monstrous in British territory, too.

How the intelligence of the elephant has grown steadily with its trunk

Thanks to a great find of remains in Egypt, the ancestry of the elephant has been clearly traced. We cannot within the limits of this chapter tell the whole story of the elephant's equipment, but the important fact is that we have got the clue to the origin of the trunk. That is the implement which has helped the elephant to develop his intelligence, just as his hand helped man. The elephant's trunk is, next to the Primate's hand, perhaps the most wonderful natural implement in nature, though we must not overlook the bill of the bird, and the mandibles of the bees and ants.

But undoubtedly the trunk has given the elephant extraordinary power. With it he smells, feeds, drinks; with it he can pick up a needle or a ponderous weight In the Indian elephant it is a one-fingered instrument; in the African it is two-fingered. Whence came this organ? It seems to have resulted from one of those experiments of nature which strike us as freakish. It began first of all with an animal which produced the lower jaw into a long, trough-like chin. We may hazard a guess at the reason for this seeming malformation. The animal was developing in height; and as it was a browsing animal, it had either to increase the length of its neck or find some other way of reaching the ground with its mouth. To increase the amplitude of the neck would have been impossible, for so vast a head could not have been supported upon so slender a column. All the long-necked monsters of old time, it will be remembered, had what seem to us absurdly small heads; they had no room for brains, and so they died out. But the elephant produced this long lower jaw.

Obviously, then, the upper part must have some correspondence The result was that, instead of adding new weight to the already ponderous head by extending the upper jaw, the nose and upper lip were gradually developed in advance of the upper jaw, and an examination of the lower side of the elephant's trunk today reveals the vestiges of the margins of the lip itself. From an exaggerated, pig-like snout the elephant fashioned a trunk, an organ which acquired the art of prehension. As the trunk increased in size, so the necessity for the long lower jaw disappeared. The lower jaw was therefore shortened, and the trunk became the means of getting food, aided by two massive incisor teeth which developed into tusks to act as instruments for digging, either for roots or in quest of water, and, secondarily, as weapons of offense and defense.

A CAPTURED HERD OF WILD ELEPHANTS CROSSING A RIVER IN SIAM

This type proved successful, and the earlier forms died out. Today the trunk is the elephant's most important organ. An elephant without a trunk would be like a man without hands, for the proboscis is the elephant's hand With it he picks his food, the tender shoots of trees, fruit, tussocks of grass or whatever it be

With it he lifts his rider on to his back and he can pick up very minute objects with it. But he does not carry his loads by means of it. Baulks of timber are carried between the jaws, or balanced across the tusks; or a stout rope, to which the timber or stone is attached, is carried between the teeth. But he does use the trunk for testing his work.

Of course, it need hardly be said the animal is exclusively herbivorous In its wild state the Indian elephant seeks the shade during the day, and wanders feeding the greater part of the night The African species is more a diurnal animal The former averages 9 to 10 feet in height but animals measuring as high as 12 have been known. The average of the African species is probably higher and the bulk greater. Jumbo, the celebrated circus elephant, stood 11 feet at the shoulder, and weighed 6½ tons, but elephants of at least 12 feet in height have been reported from Abyssinia. Probably the biggest of the two species attain pretty much the same dimensions, but elephants of from 10 to 11 feet seem somewhat more common in Africa than in India. It is impossible to state how long an elephant lives, but, from observations made upon captive animals, it is computed that 150 years is a fair average. The survey of many skulls leads to the conclusion that there has been a steady, if slight, development of brain in the elephant.

What the critics of the intelligence of elephants have to say against them

But here the student is apt to fall between two stools. There is a danger of his being led either into a too generous estimate of the elephant's natural intelligence, or, on the other hand, into taking sides with those who rate the animal's intelligence on an absurdly low scale.

The fact is that in dealing with elephants man has to start his training *de novo* with each animal, as is the case with the cheetah. Therefore to compare the elephant with the horse or the dog is to give an entirely false estimate of the mental powers of the larger animal But even with all that may be said from this point of view, no animal in the world is more educable than the elephant. No naturalist denies that

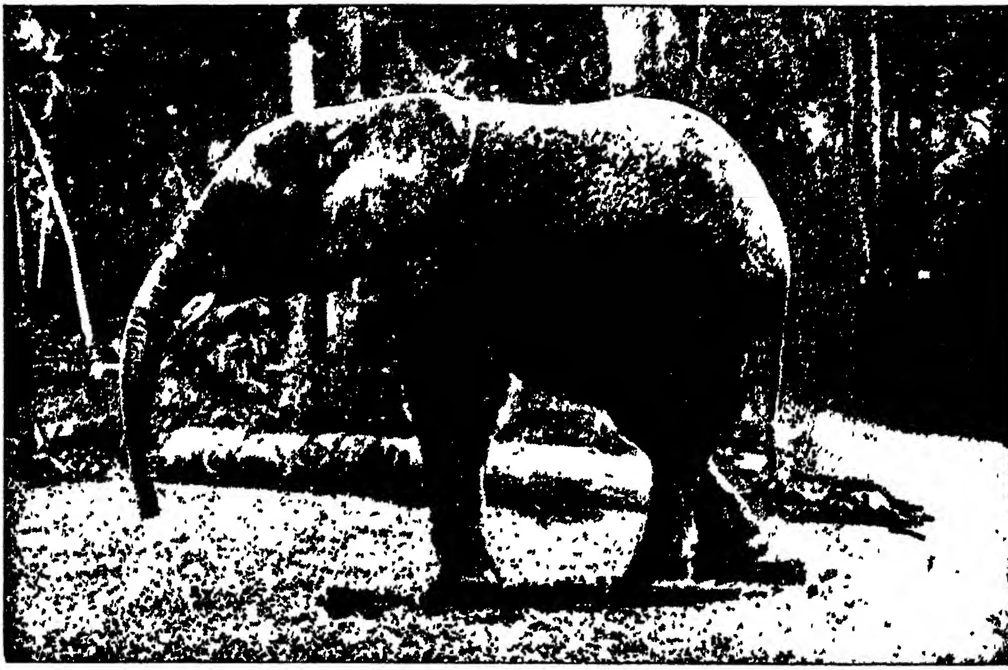
Has the big elephant more wisdom than he is credited with?

The work that elephants accomplish on public works in India, in the carrying and stacking of timber, and the placing in position of large masses of masonry in building operations — this, when all is said and done, eclipses the performance of any other animal. But while educability is conceded, the critic of the elephant complains that the animal has no originality, that it cannot deal with an unexpected situation, that it will never volunteer its services, but will let its master be assassinated before its eyes.

This may be so. But is this quite a fair line of argument? For will every dog in a sudden crisis defend its master from a murderous attack? Will not some of them run whimpering away? And is man himself always staunch in the presence of a tiger, or in face of other sudden danger?

The elephant approaches the human in his affections and in his hatreds, and there exists between him and his master perhaps a better understanding than between man and any other animal The combination between a shepherd and his dog is wonderful, but no dog ever held its puppy to be operated upon by its master. That has been done by an elephant. No animal but the elephant makes a real tool. The elephant picks a branch, strips it of all but its topmost plume of leaves, and uses this as a fan to brush away flies. Moreover, it will pull up a stake and use it as a back-scraper.

The wisdom of the elephant may not equal all that the animal's greatest admirers fondly assert, but it is certainly higher than the opposite school of naturalists would have us believe.



A LORD OF THE DARK CONTINENT—THE AFRICAN ELEPHANT

MAN'S BIGGEST ALLY IN THE ANIMAL WORLD—THE INDIAN ELEPHANT

African elephants are not tamed except for menageries, but in India the elephant is an indispensable motive-power. The contrast in the shape of the head is a notable distinction between the two species.

The usefulness of the enormous appetite of the gigantic river-hog

The elephant, then, has earned the place that he retains in the world. What are we to say of the hippopotamus? High intelligence cannot be pleaded for this great river-pig. The biggest of land animals, next to the elephant, measuring as much as fifteen feet in length and weighing some four or five tons, he has always presented a fair mark for the dart of time. He has survived because of his perfect adaptation to a singularly favorable habitat. His habit is to keep to the river by day, and to go ashore at night. He is as much at home in the water as on dry land. He is well fitted for an aquatic life, for, with ears and nostrils hermetically sealed at will, he sinks to the bottom, and can run along the river-bed with almost as great facility as upon the land. He needs to rise to the surface only once in five or ten minutes to breathe, and all day long he can browse upon the rich vegetation which the river bed and banks afford. At night, when all is still, he roams afield, there to supplement the diet which his hunt by day has afforded. He is endowed with an enormous appetite: his stomach holds between five and six bushels, and this appetite has been productive of substantial advantage to man. It has impelled him to eat voraciously of the river growths which must otherwise have choked the streams and flooded great areas far and wide.

The hippopotamus which eats too much to be allowed to range at large

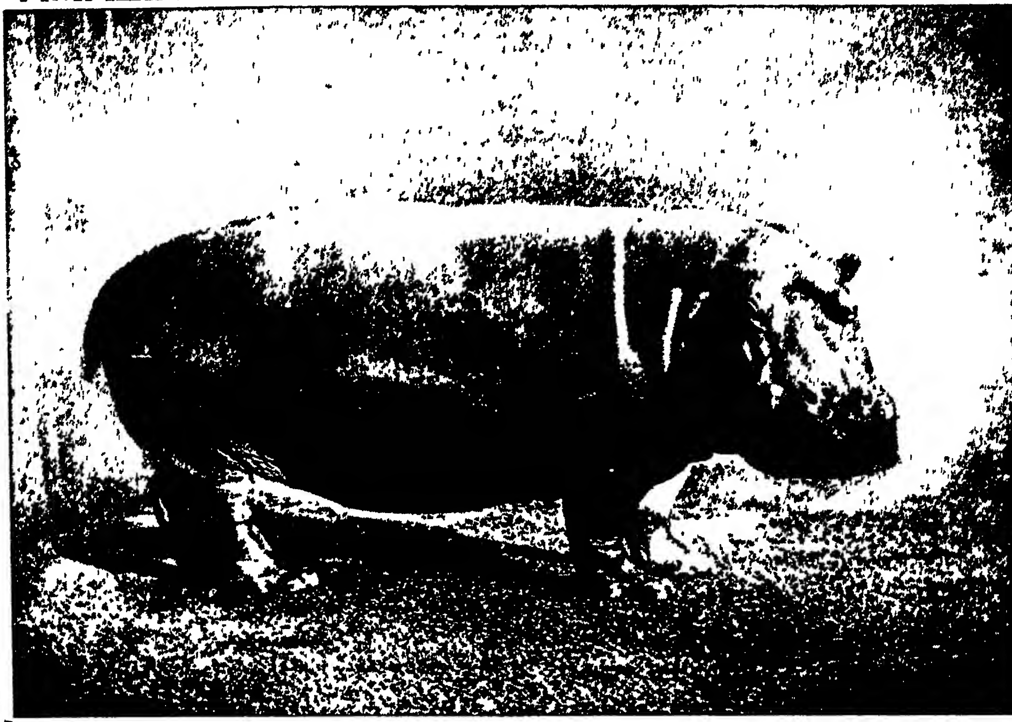
But the range of the hippopotamus today is very limited, and the genus is doomed. So long as the White Nile and other rivers clothe their banks with dense masses of reeds impervious to man, the beast is safe, but where a river bank comes within the borders of cultivated land, the river-hog must go; it levies too heavy a toll upon crops to be tolerated. So, little by little, its world, limited now entirely to Africa, becomes more and more restricted; and the time must come when these animals, if alive at all, will be known only to zoölogical gardens. It is sad, but inevitable.

Once the hippopotamus ranged all over Europe, as far south as Italy, and as far north as England, and as their remains occur in company with relics of the reindeer, naturalists are presented with a pretty little puzzle which they have not been able to solve. One theory is that the hippopotamus ranged north in the summer and returned south in the winter. This, however, postulates an activity and zest for travel to which all existing hippopotamuses are strangers Nowadays they never stray far from their homes. They travel to and from the river by well-marked paths Should heavy rain fall while they are absent from the river, they are lost, for the downfall washes away the scent by which alone they are able to find their way.

In general structure the hippopotamus has kept pretty much to a generalized design, yet he has decidedly helpful features. The forward protruding tusks of the lower jaw are admirably suited for tearing up vegetation; the high-placed nostrils are a life-saving device. Where he is secure from the attacks of men, the hippopotamus is a noisy, frolicsome beast, coming up from the bottom of the river with a rare uproar. But where men hunt him, he is cautious, and, gently nosing his way up among the vegetation, he thrusts only his nostrils into the air, and breathes as noiselessly as a slumbering infant.

It is rather tragic that the devoted mother hippopotamus is the animal most in danger. She rises frequently to the surface to enable her calf to breathe. The little one stands upon her neck, and she must rise high and advertise her presence, so making herself a good mark for the man with a gun. Navigators who make their way up rivers in small boats do not love the hippopotamus. It frequently shows a great aversion to boats, and not the stoutest-built craft is safe from it should it make up its mind to attack, as in all likelihood it will, once it sights the boat.

There is a smaller species of hippopotamus than the one we have been considering. This is a Liberian representative, a pygmy version of the other, whose habits resemble those of a big wild pig with a special fondness for water.



THE HIPPOPOTAMUS, THE BIGGEST LAND MAMMAL AFTER THE ELEPHANT

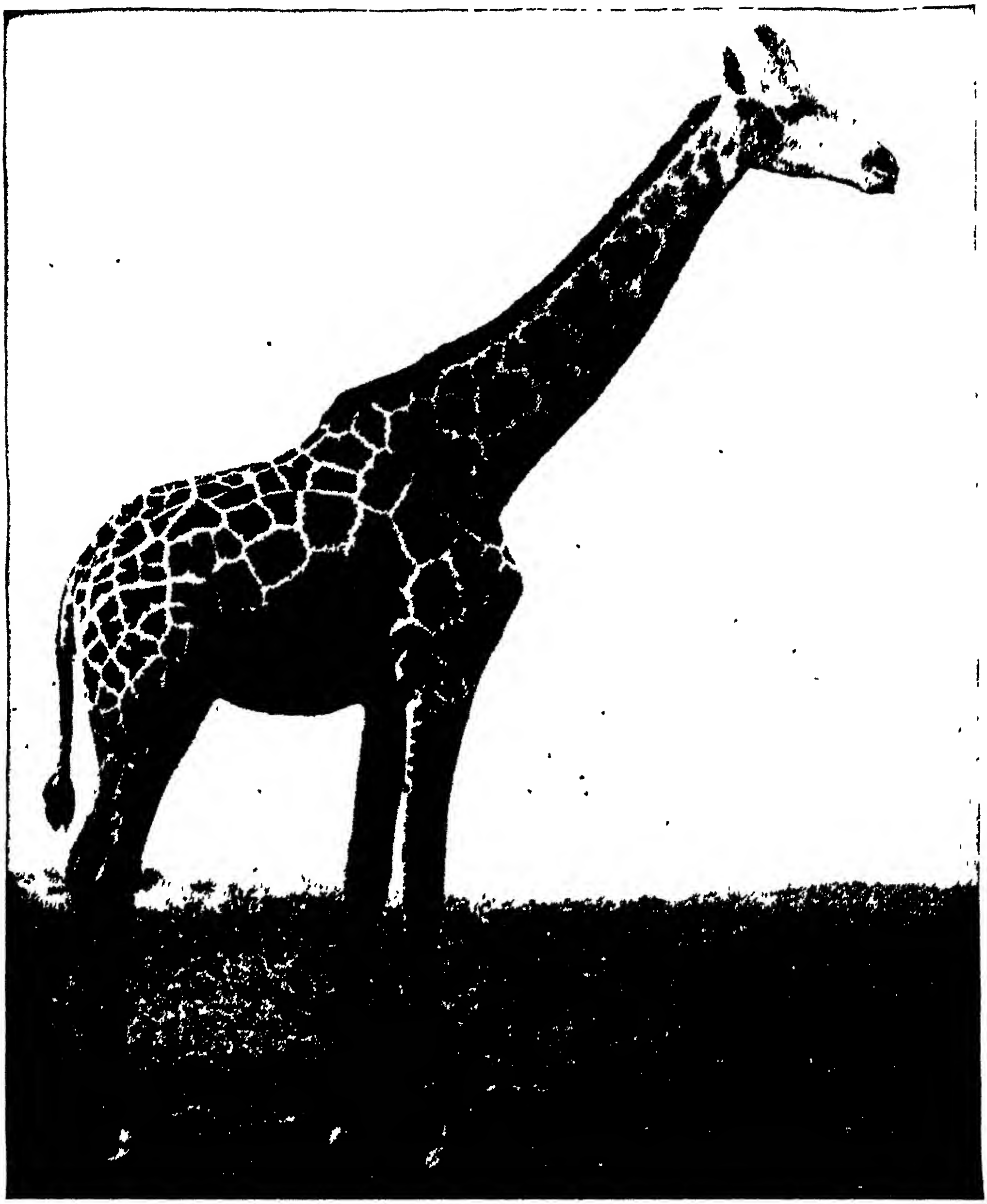
THE RHINOCEROS, A RELIC OF AN ERA OF ARMOR

Not intelligence, but a sort of unsplendid isolation has kept the hippopotamus among the survivors of the past. The rhinoceros owes his continued existence to an effective armor coupled with moderate mobility, displayed in almost inaccessible wilds.

The rhinoceros has not been favored to such an extent as the hippopotamus in the matter of habitat, but its almost impenetrable hide, its horn or horns and its immense strength have sufficed to keep it still among the living animals of the world. But innumerable species, which had the whole of Europe as well as a great part of Asia and America for their home, have become extinct. At present the rhinoceros is confined to the continent of Africa and the southeastern part of Asia Although it revels in a mud bath, it is essentially a land animal, feeding on grass and the young shoots of trees Although in weight it may not equal the hippopotamus, the height of the biggest of the genus — well over six feet at the shoulder — is nearly twice that of the latter. Therefore, in size, though not in bulk, the rhinoceros ranks next to the elephant. He has none of the dignity of the latter.

THE MOUTH OF THE HIPPOPOTAMUS

Only a whale can rival the hippopotamus in mouth-capacity, as may be easily understood from the gape of this captive monster.



THE GIRAFFE, THE TALLEST GIANT ALIVE IN THE WORLD

The habits of these animals, wherever they may be found, vary very little. During the day they rest, unless disturbed, in high grass or thorn bushes, and feed at night. They have poor eyesight, like the elephant, but their ability to detect the scent of an enemy, and especially that of man, is acute. Ordinarily they will amble away if challenged, quickening their pace, if pursued, into an ungainly gallop, sufficient to carry them beyond the reach of a man unless he be reasonably well mounted. If, however, they are suddenly confronted and see no way of escape, they will charge with great impetuosity, and either gore with their terrible horn or ply the formidable tusks with which the lower jaw is furnished.

The friendly bird-sentinel that gives warning to the ungainly rhinoceros

With its massive armor-plating the adult rhinoceros has not much to fear from animal attacks. So far as we know, there has been nothing to account for its extermination but change of climate in geological times, and, within historic times, the advance of civilization upon its preserves It is interesting to note that this huge beast depends for its safety to a certain extent upon one of those curious associations which we find in nature. The preserver of the rhinoceros is a bird, the rhinoceros bird, which, hovering about the animal in quest of insects, not only conduces to the comfort of the brute by relieving it of parasites, but contributes to its safety by the loud screeches and flapping of wings with which it acclaims the advent of a foe in the shape of man. This habit of the bird at once gives the rhinoceros the signal, when it bolts. The value of such an association is obvious, for a man might steal upwind unobserved close to a rhinoceros, were it not for the warning afforded by the feathered sentry. The rhinoceros is among the animals doomed, but his fate must have been sealed earlier had it not been for his winged ally.

The animal in which everything else is subordinated to height

And now, although to do so is to fly in the face of all conventional classification — as indeed the whole grouping of this chapter does — we pass to a very different type of giant, and one of the strangest, the giraffe, another of the animals in whose existence we should flatly refuse to believe if our eyes could not see him. He must be considered in a chapter on giants, for he is the tallest of living animals. With a height averaging over fifteen feet for the males, and from thirteen to fourteen for the females, the giraffe frequently exceeds sixteen feet, sometimes reaching eighteen. The giraffe depends for his food upon the high-growing foliage of trees, the acacia in particular. To reach it he has had to develop on lines which have no exact parallel. Everything has been done to give the giraffe height.

Long legs do not suffice; the front pair must be higher than the hind pair in order to thrust up the neck where it joins the sloping trunk. The neck itself, though containing but the usual seven vertebræ common to all mammals, is enormously elongated, and the head can be placed in a line with the neck, so as still further to extend the reach, while the tongue is a marvel of extensibility and prehension

The giraffe is one of the most specialized of animals, and should his tree-fare fail him he would be desperately pressed, for ground-feeding is a matter of the greatest difficulty, necessitating his straddling wide with his front legs in order to bring his mouth to the earth. With his flexible prehensile lips, and a tongue whose tip can be thrust into the ring of a small latchkey, the giraffe is admirably fitted for plucking the leaves of trees and avoiding their thorns.

How long can the giraffe live in the tropical desert without drinking?

But he is a puzzle to zoölogists, in that he is better qualified than any other mammal to withstand thirst Restricted now to Africa south of the Sahara, these animals are found in the desert of Kalahari, where it is believed they cannot drink for seven or eight months of the year. Indeed, they are reputed by the natives never to drink at all But there is always the possibility that desert animals know of water supplies of which men are ignorant, and the Kalahari giraffe's abstention from water may be less prolonged than is supposed.

In habits this giant is the most inoffensive of creatures. Its horns are valueless for offense or defense. Its sole weapons are its hind feet. With these it can kick with tremendous force and with such speed that the action of the leg cannot be followed by the eye. The lion is, next to merciless man, the giraffe's most terrible enemy. In a fair run the giraffe would beat the lion for speed, but with his head in the clouds, or, at any rate, the foliage, he is easily stalked.

We have known the giraffe in captivity for nearly a century, otherwise he would be an incredible beast. As it is, he is one of the strangest-looking animals in existence.

MAN AND HIS SYSTEMS

The Marvelous Living House that Human Life Inhabits, and How It is Built Up

THE FRAMEWORK OF THE HUMAN BODY

FIRST it is necessary to get some idea of man's body as a whole — what it is, and why it is what it is. Thereafter we might begin at the surface and deal with the skin, and then go on to study the deeper structures. Or we might take the various parts of the body in their turn, beginning, say, with the head, and then dealing with trunk and limbs.

To the anatomist, studying structure, and to the physiologist, studying function, neither of these methods is worth a moment's consideration, sensible and convenient though they seem. It is true that in the actual process of anatomy or dissection we must begin with the skin and the structures that lie just under it but it does not follow that this method will suffice to give us any real understanding of the body. It is true, also, that for many purposes we require to study the head, the neck, the foot and what not; and there is thus a "regional anatomy," which is the constant necessity and preoccupation of the surgeon who has to work in these regions, and must know exactly where he is, and what he may encounter at any moment. But apart from the business of dissection, and apart from the necessities of the surgeon, there is only one method of describing the body which is really worth anything. That is the method which depends upon the fact that the body is a combination of many "systems," each with its own structure and function.

This fact of "systems" is what we encounter when we look at the body of man — not as a whole, as we have lately done — but in its parts. We find that though, when we cut it, we may distinguish different layers, and though, when we seek to dismember it, it comes apart in obvious ways — head, trunk, limbs — yet it is built, not on the principle of layers, nor on the principle of repeated sections, like the joints of a centipede or a drain-pipe, but on the principle of systems.

It has a bony system, made of a special kind of tissue, for a special purpose, and found in special places. It has a muscular system, equally distinct and characteristic. Each of these systems is found in all parts of the body. But if we are wise, we shall think of, for instance, the bony system as all one, even though we find parts of it under the scalp and other parts inside our toes. This idea of systems works equally as well from the point of structure as from the point of function. Bone is bone, and muscle is muscle everywhere, as is verified when examined under the microscope. And the physiologist reports that bone everywhere supports and muscle everywhere contracts and expands.

Better still, this idea of systems is not only convenient when we are taking the body to pieces, and finding how it works, but it is the only method of study worth naming from the point of view of the life of man in the world. We think of him as a living being, with an animal body, air-breathing, food-needing and so forth, like all other living beings in many things, unique in many more. And we find systems to correspond. An animal that has to find food, and get about, has a bony system and a muscular system, and a system of joints for locomotion. An animal that has to digest food or aliment and absorb it has

an alimentary system. For excreting, or ridding himself of his poisons, man has an excretory system. For producing or controlling necessary chemicals, he has a glandular system; for breathing, he has a respiratory system; for the circulation of the blood, which serves all these purposes, he has a circulatory system, and for the life of every part, and for its own higher purposes, he has a nervous system.

This is the intelligent way, and the only intelligent way, of looking into and perceiving the body of man. It promotes and facilitates every aspect of our study, and, unlike other methods, it avoids the reproach that science, as Wordsworth said, too often "murders to dissect."

VERTEBRATE AND INVERTEBRATE ANIMALS
The sections above of an animal with a backbone and an animal with a shell show how in the one case the bony structure is inside the softer parts, and in the other case outside A similar difference appears in fruits, as in the plum and the nut.

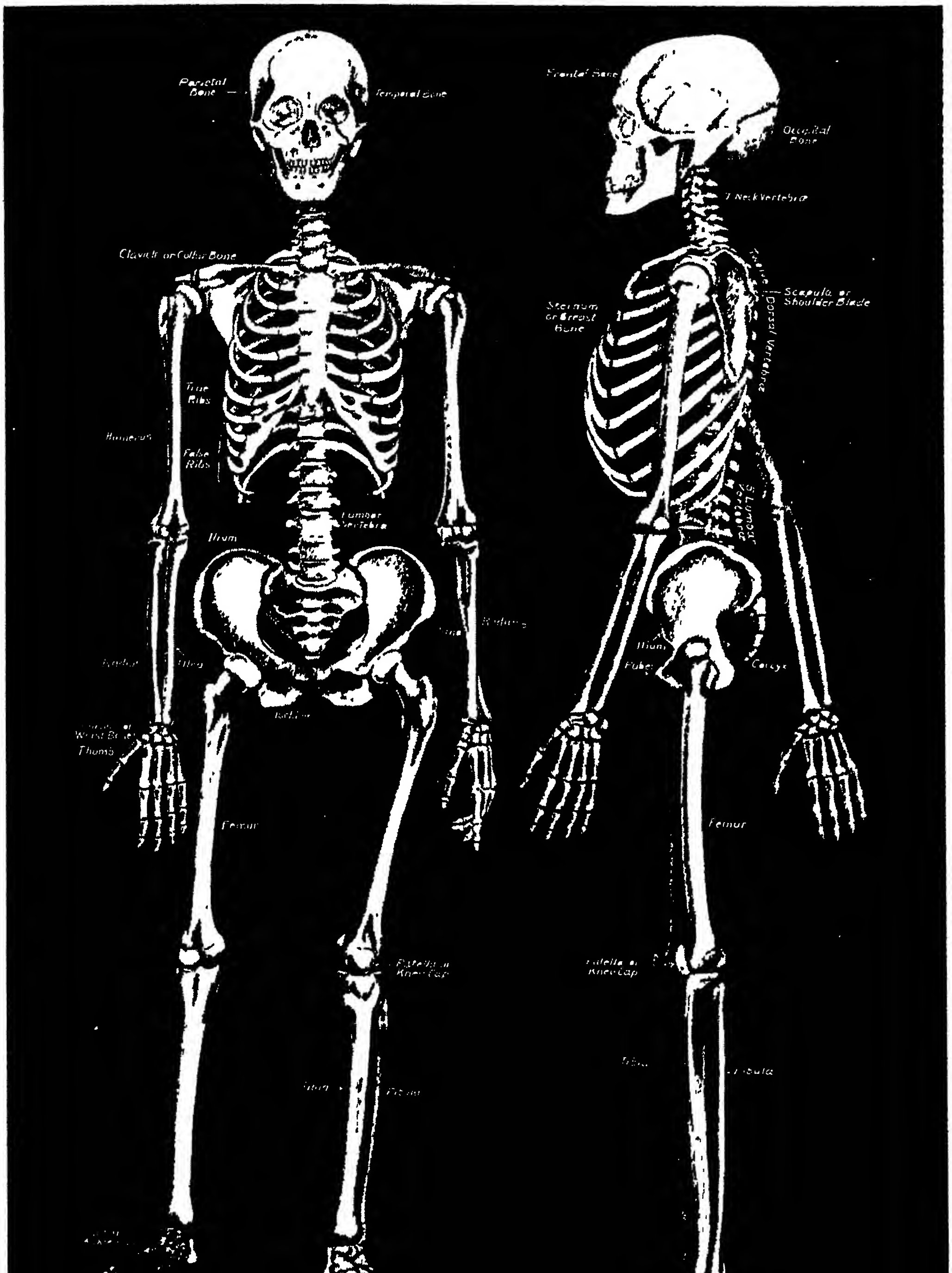
The body of man, therefore, is a complex, made by the combination and interaction of a number of systems, each of which has a definite relation to some definite need of life. If we ask what the needs of man's life are, in most general terms, the answer is that they are two, the preservation of himself and the perpetuation of his kind. Self-preservation is asserted by some to be the first law of man's being, and reproduction the second. It is questionable whether the order should not be reversed, but it suffices to treat these two great needs as coördinate and equal.

Finally, then, in this human body of ours we discern a system which is, in a sense, in the body but not of it, a system which, unlike all the others, does not exist for the body—nay, the body largely, if not wholly, exists for it. This is the reproductive system, including the "germ-plasm," the racial or parental tissue, which we find in the marvelous "germ-cells" of which the next generation is formed, and from the like of which the body that cares for them was formed. This reproductive system must be named and thought of apart from all that we have mentioned, for it is unique in function and in origin, as the study of development shows, and it is also unique and converse in its relation to the other systems and the bodily whole.

The first system to claim our attention is the bony or osseous system, the skeleton, which forms the more or less rigid framework of the body. It were almost preferable, if it were feasible, to take bones and muscles together, and think of them as the locomotor system, but this leads us on to take the nerves which order and control the muscles, and thus we learn how, though systems are many, the body is one. For practical purposes we must begin with the dry bones of anatomy, as every student does in our medical and anthropological schools.

If we look at the entire body we see that it is built on a plan of bilateral symmetry, having two halves, or sides, which are the same, yet not the same, as we learn on trying to fit a right hand into a left glove. This external symmetry is carried out by the arrangement of the trunk and head — the axial part of the body — and the limbs or appendages. The fact that there are two pairs of limbs, and also the fact that we find a succession of bony arches on each side, and a succession of knobs in the middle line of the back, suggest that the body is built not only in two-sided or bilateral symmetry, but to some extent also in the symmetry of a "linear" type, which type, however, is limited to the axial skeleton or vertebra. Since the worms are built on this latter plan of serial symmetry, depending on the repetition of a number of segments, each fundamentally

THE BONY SCAFFOLDING OF MAN'S BODY



This picture shows how the human frame is strongly built up for the protection of its vital organs, and plentifully hinged to admit of free movements, especially to the limbs.

the same as the others, some fanatics on absurd ideas of evolution would have us believe that the worms were our remote ancestors They say, "Modify the front segment, to be a sort of head, and the last to be a kind of tail, and we have what may be called the idea of a worm" However, such a conclusion is absurd, for while the segmented worms are made up of almost anatomically identical segments, the human body is not segmented in its viscera, which are entirely different at different levels. The earthworm, for instance, has primitive kidneys in each segment of its body, while we have but one set of kidneys, and one of these is at a higher level than the other

It is true, however, that our body has the repetition of the upper limbs and the lower limbs, and the repetition of the ribs, and sections of the backbone. Closer study confirms it Furthermore, if we study not only the adult but also the developing body, we discover a repetition of arches on each side of the neck, made of gristle or cartilage, which really correspond in appearance to the gill arches of the fish. But not even in the embryo do they function as such.

But to continue, let us remember that the sections of the backbone are hollow, and form between them a long tube, which at its upper end expands to form the cavity of the skull; and that the brain and spinal cord, which are in all essentials one, are found inside the skull and the backbone respectively. This may look to some as if the skull were made of expanded vertebræ, and suggest that even in the skull, which seems so unpromising for the purpose, there is evidence in favor of the argument that the body is really made from a number of similar sections, one in front of — or, in our case, above — the other. But these people must remember that, while the vertebræ are in linear order, they develop as separate bones from cells that were once cartilage cells and later ossified. The skull, however, is not developed from one vertebra but is made up of several bones, some of which were laid down as "membrane" bones from their start, and at no time were they in linear order.

The whole body built round the backbone

We may keep this idea in mind, however, when we study the skeleton, and we shall find that the whole framework of the body, and therefore the whole body itself, is all built around the backbone, which is itself not a single bone, but a long series of essentially similar bones. We must begin with the backbone for every reason, and think of it as the strong, central line, more important even than the keel of a ship, from which spring the ribs like the ribs of a ship from its keel, and attached to which is the bony framework of all the rest of the body

Upon its top is nobly balanced the skull, the bony framework, and much more, of the head; much more, for the skull not only supports the muscles outside it, the face and jaws, but is also the brain-case, the protector of the "temple's inner shrine," where man himself resides.

Striking contrast between the two extremities of the spinal column

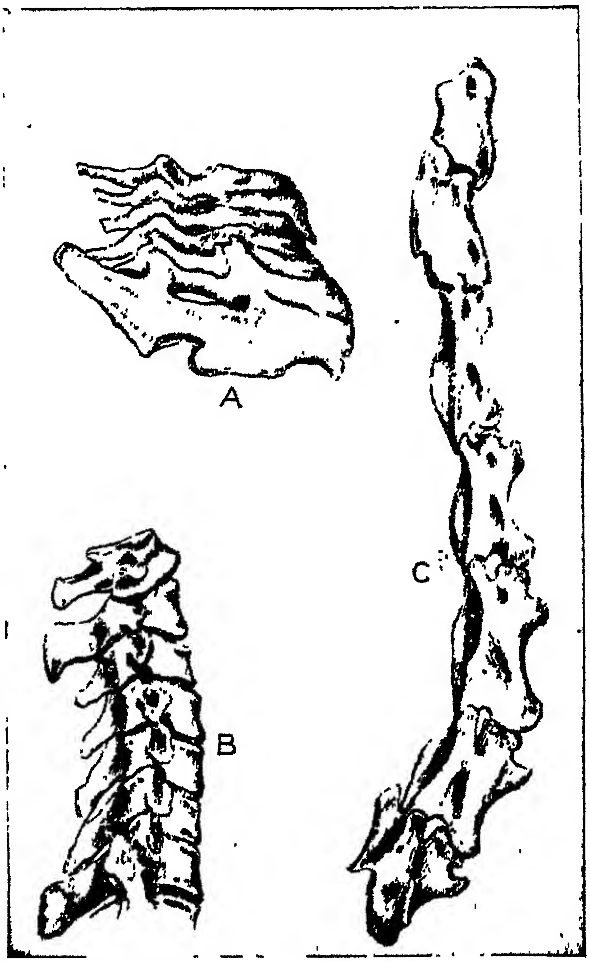
At its lower end the backbone, instead of being continued indefinitely into a visible, external tail, drops off very suddenly into four small, degenerate vertebræ, fused together into a single bone, which is tucked and curved forwards, away from the outer world, instead of towards it, unlike a true tail as found in the lower animals. What a contrast between the two extremities of our spinal column — the unprecedented head at one end, and the shriveled vertebræ at the other!

For a considerable distance along the backbone, spine or spinal or vertebral column — it has all these names — we see ribs projecting and curving outwards and then forwards and inwards until they meet or nearly meet in the front of the body, thus forming a kind of cage, box or chest, as we call it, for a special purpose which requires that the walls of the body at this place shall be more or less rigid. This is where the lungs are to lie, and they demand these ribs, together with the strong bone to which several pairs of them are attached in front — the breast-bone, or sternum.

Now we have reviewed the spine, with head, and the ribs and breast-bone. What remains is scarcely less simple in principle. At a short distance along the spine, just after we pass the neck, we find an arrangement of bones forming more or less a girdle around the spine and the body, and this we call the shoulder-girdle, with its various parts, similar on the two sides of the body Practically at the other end of the spine, just before we reach the curious little terminal vertebræ, we find a generally similar arrangement of bones, forming another girdle, which we call the pelvic-girdle, or pelvis, from the Latin word for a basin, since the pelvic-girdle is practically a spread-out basin of bone to hold the contents of the lower part of the body. There is so much general resemblance between shoulder-girdle and pelvic-girdle that we recall the idea of the "repetition of parts."

That idea is remarkably borne out when we turn from the axial part of the body to its appendages, and note that each of these two girdles bears a pair of limbs. If one gets on all-fours and plays at "being a bear," one may lose human dignity with the loss of the erect attitude, and instinctively we all feel that we are making rather fools of ourselves. But we should at least think of ourselves in this position if we are to get a just idea of the build of our body and its framework in contrast to the bodies of the lower animals that walk horizontally. The comparative architecture and scheme of the backbone and the head, the two girdles, and the two pairs of limbs in front and behind, will become clearer. Let us, then, think of ourselves erect, but try to study the erect body without forgetting what we learned when we saw it horizontal.

In these few paragraphs we have actually outlined the human skeleton, the whole framework of the body. A few tiny bones may be found inside the ears, and the bones of the face and jaws must not be forgotten, but otherwise what has been said comprises the entire skeleton. One may easily spend a lifetime upon its study, and any number of lifetimes upon its comparative study in different races, and in man and the lower animals.



THE NECK OF MAN AND ANIMALS

The bones in the neck of mammals with four exceptions number seven, whether they are thin plates as in the whale (A), elongated as in the giraffe (C), or compressed as in man (B).

The backbone, so-called, is a series of small and very peculiar bones called vertebræ. Each vertebra is built on the same plan as the others; and if one compares the vertebra of a man, a mouse and a mammoth, one finds that the essential features are similar in the vertebra which is so small that one can scarcely notice it in one's hand, and the vertebra which one can scarcely lift.

Not less noteworthy is the fact that all mammalian animals, with about four known exceptions, have the same number of vertebræ in the neck. We find seven vertebræ, neither more nor less, in the neck of a man, a giraffe, a whale, a bat, a buffalo. In the manatee, however, there are 6 cervical (neck) vertebræ while in three different edentates (sloths) there are 6, 8, and 9.

The topmost vertebra, the first of the seven in the neck, is called the atlas, for it supports the head; and this it does on two smooth surfaces, whose number is notable, for it distinguishes the mammalia from many other vertebrates, whose head is balanced at only one point on the atlas vertebra. The large and wide hole in the atlas, which is, indeed, scarcely more than a ring of bone, coincides with the great hole in the base of the skull, where the brain and the spinal cord are continuous with each other — or where, in other words, man changes the name, as he changes the name along what is really one street.

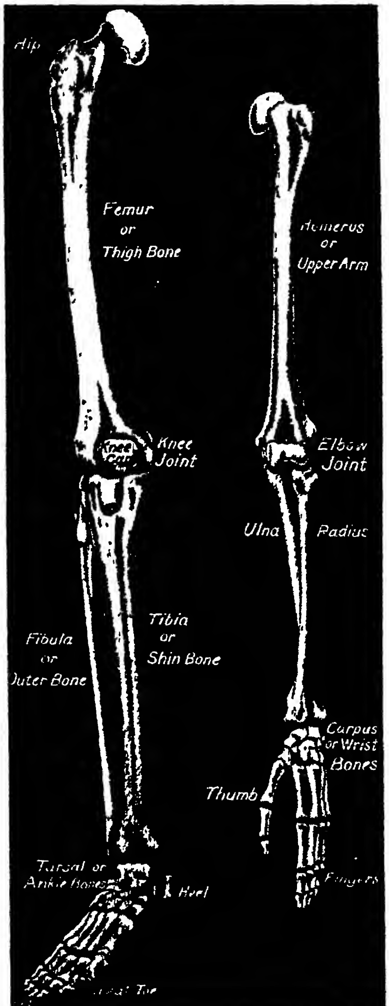
The first, or atlas, vertebra rests on the second, which is called the axis, as it well may be. It is as readily identifiable as the atlas itself for it has a great projection, which fits into the atlas, and forms an axis of rotation whenever we turn our heads from side to side. Nothing can well be more important for man the erect than free movement of the head upon the neck. He must look up and down, and from side to side, in the interests, not only of sight, but also of hearing and smell. Sight, however, is so important that, in man above all, the eyeballs move wonderfully and freely together, not even the movement of the neck sufficing for their needs. But the facility with which the neck can be moved is truly marvelous. Whenever we move the head, for any purpose and in any direction, and note the ease and range and usefulness of this movement, we should remember the atlas and the axis vertebræ, to which between them, and to their remarkable modification for the purpose, we owe it all.

BALL-AND-SOCKET JOINT
This section of the hip-joint on the ball and cup principle shows the extreme pliability of the human body It allows the leg to be moved in various directions

Notable in other animals, these movements are most so in ourselves, and for our mode of life. In very young infants the strong fibers that prevent undue movement are not developed; and cases are known where an infant has been instantly killed in consequence of rough handling of the head and dislocation of these vertebræ. In hanging, death is due, as a rule, to dislocation and fracture in this neighborhood, with consequent pressure upon, and destruction of, the spinal cord in this vital region. That is why a condemned man should be given a "drop"; and hanging which does not insure this injury is gradual, brutal and even uncertain.

The other five vertebræ of the neck are not particularly remarkable, except for their relation to each other, which is such as to give this part of the spinal column extreme mobility — evidently contrived to prevent us from being "stiff-necked." But we cannot leave such a notable and peculiar adaptation — *special* for a *general* purpose — as we find in these seven vertebræ, taken as a whole, and especially in the first two, without asking how it came about. If we are no longer to accept the view that they were made so, from nothing, and if we know that they have developed, somehow, from simple forms, we may well ask how such development occurred. Was it chance? Incredible! Was it in accord with some foreordained plan? An explanation which does not explain! Was it the result of long ages of natural selection, acting on random variations in the shape of the vertebræ, and gradually establishing the forms we see? This, the complete and orthodox Darwinian explanation, becomes yearly more difficult to believe, though it may be part of the truth or the truth may be part of it. But right here we have met the first of countless detailed facts of the body, of each one of which the same question must be asked; and of each one of similar facts, and different facts, in the bodies of all other living creatures.

We are certainly not fit to study the body of man, nor worthy to possess such a body, if we are to pass in succession by such amazing facts of structure, without at least asking ourselves how such things came to be We are clever enough at using, but we did not make them They make us



THE BONES OF A MAN'S LIMBS

The bones in man's upper and lower limbs have a remarkable similarity in number and position With one exception each bone in the leg is mated by one in the arm The exception is the knee-cap, an extra bone not represented in the elbow, which needs freer movement.

The next twelve vertebræ each have a pair of ribs jointed to, or between them, and may readily be distinguished accordingly. The neck vertebræ were so inclined as to make a curve slightly convex forwards. The next series, that bears the ribs, forms the part of the spine which is concave forwards, thus increasing, of course, the capacity of the chest and the possible expansion of the lungs Then follow five strong, large vertebræ, with no ribs attached, which make a marked and characteristic curve convexly forwards, a curve which is largely responsible for that balance of the body whereby it stands erect. This forward convexity of the vertebræ in the small of the back, known as the lumbar vertebræ — compare the term "lumbago" — is somewhat more marked in women than in men. Otherwise the facts here noted are identical in the two sexes, as are all the essential facts of the skeleton, with some exception. The bones of the average woman are somewhat slighter and smaller in consequence of her less muscularity, but the difference of sex touches no essential feature. The number of ribs in both sexes is twenty-four, so that anatomically there is nothing to explain the ancient account of woman's creation.

The next region of the backbone consists of five large vertebræ, fused together in the adult to form one bone, which is called the sacrum, from the extraordinary superstition, once current, that it was the seat of the soul The sides of the sacrum are connected with the pelvic-girdle, and thus with the lower limbs Lastly, we find the tiny coccyx, the name of the bone formed of the four fused vertebræ. This organ has some supply of nerves and blood-vessels, and even of muscles to move it, but it cannot be moved, much less "wagged," which fact distinguishes it from a real "tail" The sacrum and the coccyx are curved concavely forwards; and this completes the list of such normal curves of the spine as are easily seen and recognized in a side-view. To some extent we sit upon the sacrum and coccyx, but mainly upon the ischia, or sitting-bones, which are a specially developed part of the pelvic-girdle. This girdle is a complete one, meeting in front to complete that large bony ring in the middle of the pelvis, or basin, of which we know the sharp and well-marked outer and upper edges, just below our waist on either side.

The shoulder-girdle is much smaller and weaker than the pelvic-girdle, and much less completely deserves the name of a girdle at all. We are all familiar with the collar-bone, or clavicle, on each side, and with the shoulder-blade, or scapula.

On each side of the shoulder-girdle and the pelvic-girdle we find a cup-shaped hollow or socket, in which rests and moves the smooth, rounded head of a great bone.

These are the two shoulder-joints and hip-joints, the former two being magnificent examples of a ball-and-socket joint. And here we have reached the limbs.

The duplication of bones in the upper and lower limbs

When we compare the upper extremities (arms) with the lower extremities (legs), we find that the skeleton of the limbs is notably similar in plan. The upper arm has a single bone — the humerus — and the thigh has a single bone — the femur Humerus and femur are jointed to the shoulder-girdle and the pelvic-girdle respectively by a joint of the same type. Upper and lower limbs, or arm and leg, as we must call them in the case of man, who uses them for such different purposes, are both alike in that the piece which is molded on one bone is succeeded by a piece which is molded on two — the humerus being jointed, at the elbow, to the radius and ulna, and the femur, at the knee, to the tibia and fibula. The knee and the elbow are thus naturally similar in the general principle of structure, and are essentially made for movement in one plane, unlike the ball-and-socket joints we have just seen. In each case, also, the skeleton of the limb breaks up from one large bone to two smaller ones.

When the hand lies with the palm forwards, the radius and the ulna lie parallel in the forearm, the radius being to the outer side. If, now, the hand be turned over, the lower end of the latter makes a kind of curved movement — with its center at the elbow — from which the bone gets its name "radius"; and its lower end now crosses over the ulna. It is part of the ulna that makes the projection at the back of the elbow, and it is the ulnar nerve that we excite when we say that we have hit our "funny bone."

The need for the knee-cap proved by the unshielded funny bone of the arm

The corresponding part of the knee is its front, and there we do find an extra bone developed to strengthen the great rope or tendon of the muscle which pulls over the front of the joint. This bone is the knee-cap, very interesting and useful, but not part of the essential scheme of the skeleton of the limb, for medical science has found it absent in entire families.

The tibia is the shin-bone, and the fibula, or clasp, lies on its outer side, forming a sort of clasp between ankle and knee. We can readily feel the head and the lower end of this bone, but the intervening part is well covered with muscle.

Again the limb breaks up, and the two bones of forearm or lower leg are succeeded at wrist and ankle by a number of small bones, of a wholly different shape. The case is simplest in the wrist, where the two bones of the forearm yield to two rows of four small bones. The general plan of the ankle is similar And now we may perceive what is the idea. The limb, which left the trunk in one big, strong piece, is gradually breaking itself up until it shall end normally in five separate digits — our fingers and toes. However, some abnormal human beings have had six digits instead of five, while in the lower forms of vertebrates the number varies from one to six.

We need not, of course, here insist upon the perfectly self-evident usefulness of this arrangement whereby the limb ends in fingers or toes — the toes, of course decadent in ourselves, and thus not illustrative of the point. But we must insist that the anatomy of the limbs, the succession of joints and the gradual substitution of more and smaller bones for the one strong shaft with which the limb starts, is only to be understood intelligently, from the point of view of man as a whole, if we realize what it is that this limb is designed for, and what it is that it wishes to be capable of doing.

Of course, there are important differences in detail between the wrist and the ankle, for the ankle is largely modified to serve the peculiar attitude of man, and the wrist to serve the multiple uses of his hand. Obviously, there is nothing in the wrist to correspond to the large bone which forms the skeleton of the heel, nor to correspond with those features of the foot which help to form its mobile, strong and delicate arch.

But the group of bones at the wrist, and the group of bones at the ankle, including those which form the skeleton of the back part of the foot, agree in presenting, towards the extremity of the limb, a surface for jointing with a series of five small, long bones, built much after the fashion of the long bones seen higher up the limb, but now five in number, as compared with one or two. These are the metacarpals and metatarsals — the bones beyond the carpus (or wrist), and the tarsus (or corresponding part of the foot) respectively. They, in their turn, are jointed to series of similar bones, the skeleton of the fingers, of which three are found in each finger and toe, with the exception of the great toe and the thumb, which only have two Here the skeleton of each limb ends; and we observe how the similarity of design, in general and in particular, which began with the ball-and-socket joint at shoulder and hip, is maintained to the detail of the small bones with which all the limbs end.

The skeleton of the head remains to be considered. We recognize at once that the head consists of two parts — the skull, or cranium, and the face. They are close together, but they are plainly distinct; and one of the most marked features of human development is the small size of the face compared with the skull in a baby, and the great relative growth of the face in later years. The truth is the skull contains the brain which presides over development, so that its own development, in all but its highest parts, must be early.

THREE VIEWS OF THE HUMAN SKULL, FROM THE TOP, FROM BELOW, AND IN SECTION

The upper part of the skull, or cranium, seems to be one large, hollow domed bone, but it is really three, that are loosely connected in infancy but are joined firmly together in later life The base of the skull and front around the face are formed of strong, closely jointed bones, only one of which has a movement, and that is the lower jaw

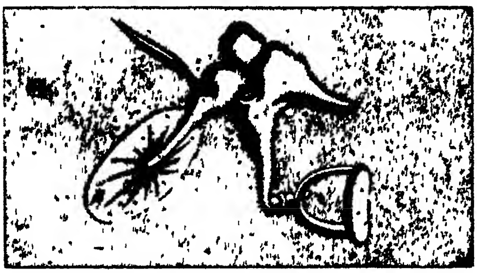
Everywhere in the skeleton, so far, we have met movable joints, though we have not yet looked at them closely In the head, though we find numerous and complicated bones, we find only one movable joint on each side, that which joins the lower jaw to the skull, not counting the pair of joints between the head itself and the atlas vertebra. The upper jaw, for instance, has no movable joint with any other bone, and if we suppose that we can move it independently, as we can move the lower jaw, we are mistaken We think we feel it moving, but that is a delusion. We cannot move the upper jaw without moving the whole skull.

The various bones of the face are concerned with its various functions, and thus comprise the jaws, in which we find the teeth, not bones, but somewhat allied to bones in some ways; and the bones of the nose, the cheeks, and the orbits, or hollows where the eyes lie and move. These bones are the framework of the face, and profoundly affect its appearance. Students of man have spent much time upon this question, especially in regard to the so-called "facial angle," which indicates the general shape of the face, and expresses, with some convenience, part of the difference between the face of a negro and that of a European man. But if we are to confine ourselves to what is not open to fallacy, we need say no more than that in the lower races of man the jaws protrude, whereas in the higher races the front outline of the jaws is more nearly vertical.

The difference between man and beast as seen in the facial angle

These differences give us, respectively, the prognathous and orthognathous types of face; and we find in them, perhaps, as notable differences between types of men as can be named — none the less so because the prognathous jaw is so evidently like the jaw of many animals, including the anthropoid apes, and thus increases the impression of lower physical type in the races and individuals who display it.

The skeleton of the skull consists of a number of strong, hard, compact bones, of very complicated form, which are firmly and rigidly jointed together to form the base of the skull; and of other bones which are stretched and expanded so as to hold the brain. These latter bones, in the devel-



THE SMALL BONES THAT HANG IN THE EAR
Between the drum of the outer ear and the drum of the inner ear three minute connected bones are stretched across the chamber of the middle ear. They are the hammer, the anvil, and the stirrup, named from their respective shapes

opment of the individual, grow from membranes of which we have already spoken; and the points where the bony tissue first was laid down remain always more or less conspicuous.

They furnish worthless and absurd indications to "phrenology" — a "science" which, however, is not in all respects so foolish, as we shall later learn. The bones of the cranium are made of two plates, inner and outer, with looser bony tissue between; and sometimes this intervening part communicates with the outer world and is expanded to form an air space. These air spaces are also regarded with nonsensical concern by the phrenologist, who supposes them, or pretends to suppose them, to indicate some special development of brain and corresponding fact of character.

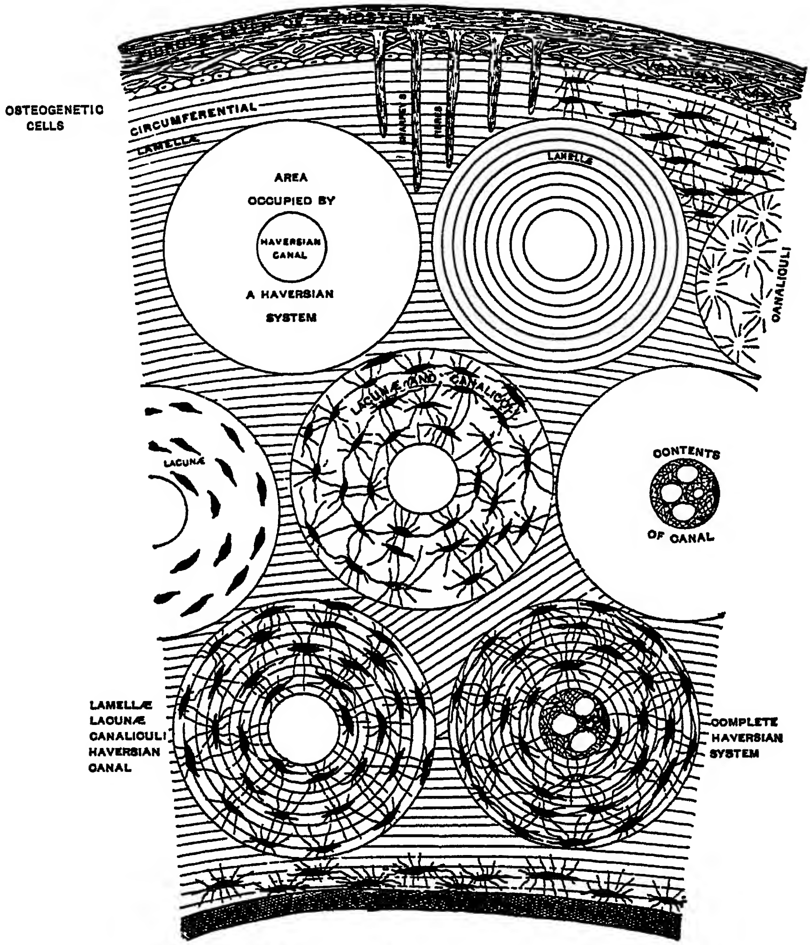
What he takes in ignorance or guile for brain is only air, however. These air spaces are larger in men than women, and their development above a boy's eyes, at puberty, distinguishes this part of his skull from his sister's. In consequence, the skull of a man appears to recede more than that of a woman, the cause not being a defect in the male brain, but the addition of larger air spaces within the frontal bone.

Such, in brief, is the skeleton or bony system of man. If we think of it as merely the framework of his body, we fall far short of the truth. It is that, but it is much more. The rest of the body is molded upon it. But in one all-important respect it is almost like the skeleton of an invertebrate, which is outside its body, for the central nervous system, brain and spinal cord, are found inside the skeleton, in the skull and backbone.

The bone-cells that, working in the dark, build up our framework

In this respect the skeleton is thus protective; it incloses and protects the most precious parts of the nervous system. That is not nearly all. The skeleton is also made for locomotion. Its parts are jointed, and these joints, with the notable exception of those in the head, are movable. Thus, as the study of muscles and joints will show, this framework of the body serves also to move it as a whole from place to place, and to move its various portions in relation to other portions. Lastly, by an extraordinary device, we find that the interior of the long bones, such as the ribs and the various bones of the limbs, is filled with what we call bone marrow, and that this bone marrow by no means exists to nourish the bone, but is the great factory of the blood. Within our ribs and shins, from second to second, are being bred and fledged countless millions of red blood-cells, which compensate for the incessant death-rate of these short-lived units of the body.

This fact should suffice to remove the delusion that bone is a lifeless object, made once for all, and then left to serve a purely mechanical purpose. The minute anatomy of bone and of the bone marrow soon disproves that notion.

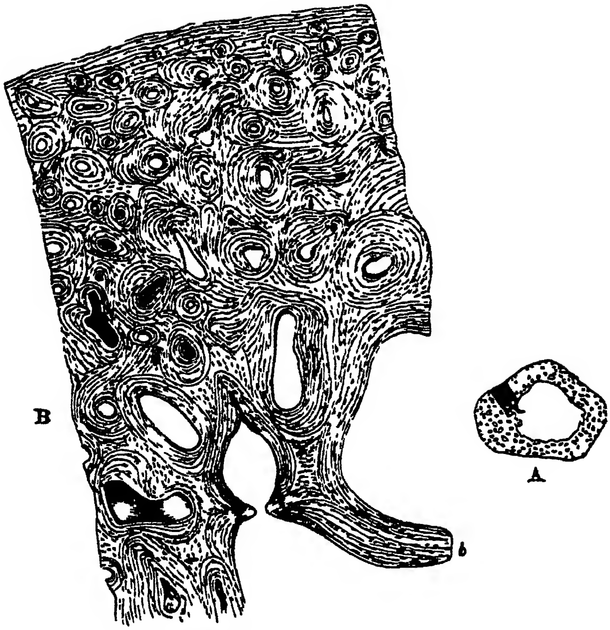


From Gerrish's *Anatomy*, Lea & Febiger

A DIAGRAMMATIC CROSS SECTION OF BONE

A small part of a transverse section through the center region of a long bone is here represented diagrammatically and greatly enlarged At the upper part is shown the outside covering of the bone, which covering is known as the *periosteum*, meaning "around the bone" At the lower part appears the layer that lines the *marrow cavity* of the bone This layer is called the *endosteum*, which means "within the bone" Between the periosteum and the endosteum is shown the *compact tissue* which consists largely of a rather regular series of the so-called *Haversian systems*, each of which is circular in outline and runs lengthwise of the bone or osseous tissue A *central canal* perforates each system. In the first one is shown only the area occupied by a single Haversian system, in the second are seen the concentric layers or *lamellæ* In these lamellæ are found *lacunæ* (little lakes) which have little radiating canals joined to them. These radiations are called *canaliculi* Finally all the structures composing a complete Haversian system are graphically shown. Between the Haversian systems are *intermediate* and *circumferential lamellæ* While only a few of these lamellæ are represented as lodging lacunæ, it must be understood that there are lacunæ in all parts of these structures The periosteum is made up of two layers. The outer layer is the *fibrous layer;* the inner layer is the *vascular layer*. The rivet-like *fibers of Sharpey* project inward from the fibrous layer and thereby serve to knit the fibrous layer more securely to the bone

And if anyone in spite of all this is disposed to think lightly of bone nevertheless, let him study the development of, say, the thigh-bone, or a bone of a finger of a baby, and its gradual growth, in the same form, to many times its original proportions. This miracle actually happens, though it is all but incredible, and though few men in a thousand may have ever thought of it. The formation of such a bone is achieved originally by a number of cells whose nature it is, somehow, to produce bony tissue They lay down, on a basis of cartilage, a rough outline of the future bone, like a sculptor's block of marble Thereafter there appears a number of larger cells, which cannot make bone, but can destroy it. They play the part of the sculptor's chisel, and dissolve away the bone already made, in just such a fashion as to give it its characteristic shape, with a bulge here for one pur-



From Gerrish's *Anatomy*, Lea & Febiger

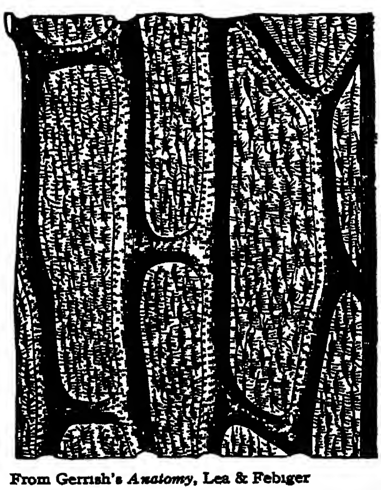
CROSS SECTION OF A BONE TISSUE

In part A of this figure is represented a cross section of a long bone, natural size In part B is shown the darkened area of part A, magnified 20 times While this magnification is not large enough to reveal the canaliculi, it does show Haversian systems of different sizes, central canals, lamellæ, and lacunæ, exactly as they appear under the microscope (These same structures are the ones that are shown diagrammatically in the figure on the preceding page.)

pose, a ridge for another, a groove to hold a nerve, a hole to admit a blood-vessel to the interior of the bone, etc.

This these cells do, until the bone on which they work conforms to the ancient characters which similar bones display in all human beings, past and present. They are microscopic cells, and know nothing; they work in the dark, without overseer or plan or previous experience, and thus they do their work. The facts of sensation, much more the facts of memory and intelligence, are hard enough to fathom, but in some ways this everyday, unnoticed feat of the bone-chiseling cells, which wander about and dissolve a little here and a little more there, and so produce a thigh-bone or a shoulder-blade, which they never saw and know nothing of, beggars the understanding more utterly still. Modern science knows much, and can do much; it has observed the growth and construction of the bones, and found out the facts, only to find itself in the presence of a fact which leaves it gasping.

It is truly remarkable that this most utterly insoluble of problems should have struck the imagination of the wise king to whose words the microscope of the embryologist only adds force: "As thou knowest not what is the way of the spirit, nor how the bones do grow in the womb of her that is with child, even so thou knowest not the works of God who maketh all." Evolution changes Solomon's terminology, but only makes his argument more cogent still We can make a comparative study of the bony skeleton, from the earliest bony fishes up to ourselves. We can examine by the microscope and our coal-tar dyes "how the bones do grow" in the development of the individual, and even seem to make Solomon's argument obsolete. But the truth is as Herbert Spencer taught: "The larger the sphere of knowledge, the larger its area of contact with the unknown." But our unquenchable desire for more knowledge and ever more will not be subdued nor satisfied on that account.



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LONGITUDINAL SECTION OF BONE TISSUE

The Haversian systems in this figure have been cut lengthwise through their very center thus exposing to view the central canals of several systems Some of these central canals communicate with those of neighboring systems The dots shown in these canals are the openings of canaliculi The dark ovals between the canals are lacunæ. Some of these lacunæ show the threadlike canaliculi connected to them.

RADIO COMMUNICATION

How Oscillating Electrons Produce Vibrations in the Ether that Fills All Space

THE WIRELESS TELEGRAPH AND TELEPHONE

WHEN James Clerk Maxwell, a distinguished English mathematician, suggested in 1864 that the light which we receive from the sun was transmitted through the intervening 93,000,000 miles of space by rapid vibrations in the ether, he also predicted the probable existence of slower ether vibrations which would produce no effect on the eye Many scientists thereafter attempted to prove their existence. The first convincing proof of their presence was established in 1886 by Dr. Heinrich Hertz, a young German professor. The honor for the discovery of the transmission of energy through the ether may then be shared by Maxwell who predicted it and Hertz who produced and detected the vibrations

Hertz produced the vibrations electrically by discharging a condenser through a short air-gap attached to the terminals of the condenser. The ether vibrations were detected by the spark produced in a short air-gap in a single loop of wire located at some distance from the condenser He thus demonstrated that an electric spark at one place will produce an electric current in a wire at another place. He attributed the distant effect of the spark to ether vibrations which carried some of the energy of the discharging condenser to the loop of wire. Hertz also demonstrated that these ether vibrations could be reflected in the same manner that light is reflected from a mirror but differed from the light vibrations in that they would pass through substances which do not transmit light.

Sir Oliver Lodge, then a professor at the University of Liverpool, and Professor Righi of the University of Bologna, gave considerable attention to the discovery of Hertz and made many investigations of the properties of ether vibrations. In 1889 Professor Edouard Branly, a French physicist, made the important discovery that a small mass of metal filings placed

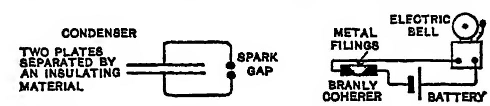

DIAGRAM ILLUSTRATING USE OF BRANLY COHERER

in a glass tube would become more compact under the influence of ether vibrations. With the Branly coherer it was then possible to ring a bell at a distant point by discharging a condenser through a spark-gap, as shown in the figure. When the terminals of the charged condenser are brought near enough together to produce a spark in the gap the ether vibrations cause the loosely packed metal filings in the coherer to become compact enough to complete the connection between the battery and the bell.

The experiments of Hertz, Lodge and Righi were directed toward a better understanding of the properties of the ether vibrations, and none of these scientists attempted at first to develop any kind of signaling device. The work of Hertz was brought to an abrupt end by his premature death in 1894. Guglielmo Marconi, a young Italian, became interested in the investigations of Righi and the other scientists, and in 1895 began to experiment for himself with the effect of distant sparks upon coherers. Marconi very quickly discovered that the ether vibrations would influence the coherer at a greater distance if one side of the spark-gap and the coherer

was connected to ground and the other side of each was connected to a vertical wire By connecting one winding of an induction coil to two metal spheres — as Lodge had done previously — he was able to operate a telegraph sounder several hundred feet away by closing the battery circuit of the induction coil as shown in the figure. Marconi also kept the filings in the coherer in vibration by means of an electrically driven tapper so that after being compacted the filings would be loosened again and respond to the next signal.

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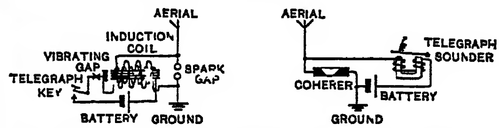
GUGLIELMO MARCONI

The first inventor of a successful radio telegraph.

At this time many other scientists became engaged in the development of wireless telegraphy. Experiments were conducted in England by Sir Oliver Lodge, Dr. Muirhead and Captain Jackson; in Russia by Count Popoff; in Germany by Professor Slaby; in France by Professor Branly; and in the United States by Nikola Tesla, Professor Fessenden and Dr. De Forest. Marconi made greater progress than the others, however, and in 1896 obtained his first wireless telegraph patent in England.

Under the patronage of the British government he began an extended series of experiments in which the distance of signaling was increased gradually from a few hundred feet to several miles In 1899 he established wireless telegraph communication across the English Channel, a distance of thirty-two miles. In all of these experiments the equipment was essentially the same as that which he had first constructed The greater distances were attained by producing stronger sparks and by erecting higher aërials.



MARCONI'S FIRST WIRELESS TELEGRAPH SENDING AND RECEIVING STATION

The Wireless Telegraph & Signal Company was organized in 1897 to develop the Marconi patents. The rights to the Lodge-Muirhead patents were purchased later and the name changed to Marconi's Wireless Telegraph Company. In 1900 Marconi was able to send wireless telegraph messages a distance of 200 miles and the next year he began the construction of two wireless telegraph stations for transatlantic service. One was located at Poldhu in Cornwall and the other at Wellfleet on Cape Cod. Both their aërials were blown down shortly after they were erected, but Marconi arranged to have the Poldhu aërial reconstructed, and started for St. Johns, Newfoundland, where he proposed to erect a temporary kite aërial. On the 12th of December, 1901, Marconi at St. Johns heard the repetition of three dots, the code signal for the letter "S," which came to him from the Poldhu station. He immediately began the construction of another wireless station at Cape Breton, Nova Scotia, and in a short time commercial messages were sent regularly across the Atlantic. Another wireless station was constructed at Clifden, Ireland, to take care of the increasing volume of traffic. Although the Wellfleet station was eventually placed in commission it has since been superseded by more powerful stations at Marion and Chatham.

The electron theory

The most recent theory regarding electrical phenomena is that the atoms of which all substances are constructed consist exclusively of small particles of electricity Some of these particles, larger than the others, are said to be "positive," and the others, the smaller particles, are said to be "negative" We thus have in each atom a mixture of two kinds of electricity and it is believed that the nature of any substance depends solely upon the relative number and arrangement of the positive and negative particles. The positive particles in an atom are called "protons" and the negative particles "electrons" Attempts that have been made to determine the size of an electron indicate that its diameter may not be greater than one-millionth of one-millionth of an inch

Since it is known that a positive particle of electricity attracts a negative particle, it has so far proved difficult to explain why the particles within an atom do not rush together and become neutralized. This is a problem which is engaging the attention of many modern scientists. In materials which are known to conduct electricity well, it is believed that some of the electrons — that is, the negative particles — in the atoms are not held closely to each atom but under certain influences may move about within the material. In materials which conduct electricity poorly — called "insulators" — it is believed that the electrons are held closely to the atoms and cannot move about unless acted upon by powerful influences. The influence which produces motion of the electrons is known to originate in certain chemical batteries and in rotating machines called "electric generators." All batteries and direct current generators cause the electrons to move in one direction, while alternating current generators cause the electrons to oscillate back and forth. Electrons in motion in any wire constitute an "electric current," and it has been determined that when the strength of the current is one ampere more than 6 billion billion electrons pass a given point in the wire in one second.

It is now known that when Hertz discharged his condenser through an air-gap, an oscillating current was established in the wires connecting the terminals of the condenser. The alternating current supplied to most of our lighting circuits oscillates sixty times in a second and the maximum value of the current in either direction remains unchanged while a lamp is turned on. This is called a "low frequency undamped alternating current" The current established by a discharging condenser may oscillate several million times in a second, and the maximum value of the current in each direction rapidly diminishes to nothing in a small fraction of a second. This is called a "high frequency damped alternating current."

Application of the electron theory to radio communication

When any device which produces a to-and-fro motion of the electrons is connected between the ground and an insulated aërial wire the electrons will be made to oscillate in the wire. Hertz furthermore established the fact that oscillating electrons — as we now explain it — will cause other electrons in a distant wire to oscillate at the same frequency. This phenomenon, it will be seen, is the basic principle of radio communication. It may fairly be stated that the manner in which an oscillating electron may act upon another electron through the intervening space and cause it to oscillate in unison is not clearly understood. While many scientists have rejected the vibrating ether theory and question the existence of an ether, the explanation of radiant energy by the ether theory is comparatively simple and is therefore adopted in this exposition of the matter.

The ether theory presupposes that all space, whether occupied by any substance or not, is filled with an elastic medium which is thrown into vibration by oscillating electrons. The vibration of the ether which first starts in the vicinity of the oscillating electrons is propagated through the ether at a velocity of 300,000,000 meters or 186,000 miles per second, the velocity of light,

Let us assume for convenience' sake that the electrons in a wire oscillate back and forth at a frequency of 1,000,000 complete oscillations per second. It will then be seen that the electrons move back and forth once in every millionth of a second During this single oscillation the ether disturbance will have traveled one-millionth of 300,000,000 meters, or 300 meters. If we think of an ether disturbance as a traveling wave similar to that observed when a stone is dropped into a quiet pond of water, it will be seen that the crest of the wave will have traveled 300 meters in the case cited during one complete oscillation of the electrons. This distance, obtained by dividing the velocity of propagation — always 300,000,000 meters per second — by the frequency of the oscillating electrons in cycles per second, is called the "wave length" or the distance from crest to crest of the ether vibrations. It will thus be noted that a short wave length implies a high frequency, and a long wave length a relatively low frequency of ether vibration.

The ether theory furthermore presumes that the electrons in any substance intercepted by vibrations propagated through the ether will be made to oscillate at the same frequency While one side of the transmitting or receiving equipment is connected to ground in most wireless installations and the strength of the signals is increased thereby, it is not necessary to make this connection. Signals may be sent from one airplane to another, for example, without any connection to ground. It may also be mentioned in connection with the ether theory that the ether vibrations must follow the curvature of the earth in long-distance transmission, and the cause of this bending of the path of the ether vibrations has not been clearly explained. One theory is that since the earth is surrounded at a great distance by a high conducting hollow sphere of gas, the ether vibrations bound back and forth between the earth and the outer conducting sphere. If this theory proves to be true it will eliminate the possibility of radio transmission from the earth to another planet, or in the reverse direction.

The significance of tuning

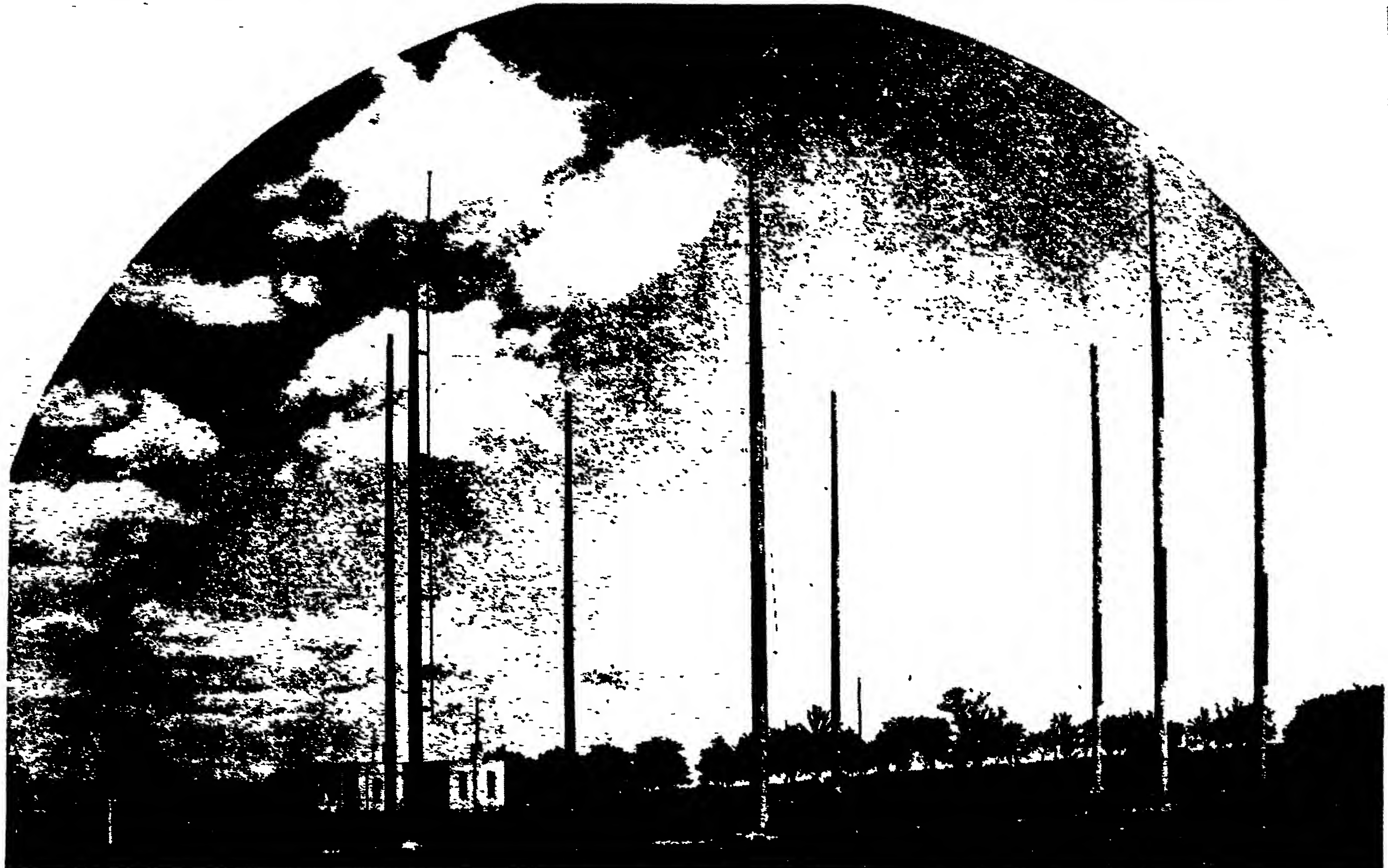
The number of electrons per second passing a given point in a wire, or a current established in a wire due to any influence, depends upon four things First, there is the effect of the pressure exerted upon the electrons by the device in which the pressure originates An alternating current generator developing a maximum pressure, called an "electromotive force," of 10,000 volts will cause 1000 times as many electrons to oscillate as will a similar generator of only 10 volts maximum pressure.

A second factor is the material of the wire in which the electrons oscillate. Many more electrons will oscillate under a given alternating pressure in a silver or copper wire than in a material such as glass or rubber. The silver or copper is said to have a lower resistance to electron motion than the glass or rubber. The resistance — measured in ohms — is less in a short than in a long wire, and is also less in a wire of large diameter than in one of small diameter A high frequency current, furthermore, flows near the surface of a wire so that a hollow wire may conduct as well as a solid one.

Due to the third effect — the inductance effect — the oscillating current is less if the wire is wound in a coil than if it is straightened out. If a piece of iron is placed within a coil conducting an oscillating current the current is greatly diminished and the use of iron in connection with radio apparatus should be eliminated for this and many other reasons. The greatest alternating current will be established in a given wire if it is doubled upon itself so that the current will flow from one end to the middle of the wire and then back over nearly the same path. This property of the shape of a winding which affects the strength of an oscillating current is called its "inductance."

The fourth effect — called the "capacitance" effect — is obtained when a wire is broken and the ends are attached to two metallic plates separated by an insulator This device is called a "condenser." The strength of the alternating current depends upon the area of the plates, the thinness

ANTENNA SYSTEM OF STATION KDKA AT EAST PITTSBURGH, PA.

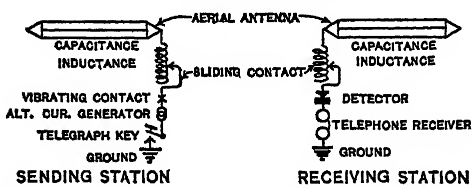


Courtesy of Radio Corp. of America

Programs broadcast through the short wave transmitters of this station are heard regularly in all parts of the world.

of the insulation between the plates, the nature of the insulating material and the frequency of the current. The most important property of the capacitance effect is that its influence at any instant upon the oscillating electrons is just opposite to that of the inductance effect. When the inductance effect tends to push the electrons back the capacitance effect pushes them onward. It will thus be noted that if the inductance and capacitance effects are properly balanced they will neutralize each other, so that the electrons will oscillate as if neither were present.

In the most common type of antenna — called the "aërial antenna" — the aërial wires are separated from the ground by air and thus form a condenser. At the sending station shown in the figure the



ESSENTIAL PARTS OF A MODERN WIRELESS TELEGRAPH SENDING AND RECEIVING STATION

capacitance effect may be eliminated by connecting a variable inductance in series with the antenna. This inductance may then be adjusted for the frequency of the antenna current, so that the strength of the antenna current will depend only upon the pressure developed by the generator and the resistance of the antenna wires and ground. Although the antenna circuit contains an air-gap equal in length to the distance from the ground to the aërial wires, the inductance and capacitance effects will neutralize each other, so that the current will be as strong as if the end of the antenna were connected directly to the ground.

At the receiving station, where the oscillating influence of the ether vibrations is always very weak, it is important that the effects which restrain the oscillation of the electrons be reduced to a minimum. This is accomplished again by adjusting the inductance so that the capacitance effect will be eliminated. Since the amount of inductance required to balance the effect of the capacitance depends upon the frequency of the vibrating ether, opportunity is also given to tune the receiving circuit to the particular frequency of the message desired. In this way a receiving circuit acted upon by a variety of ether vibrations of different frequencies may be made to respond with greater strength to one frequency than the others. It will thus be seen that when a receiving station is operated in a region where the ether is subjected to many complex vibrations the reception of a particular message will depend upon the ability of the receiving operator to tune the receiving antenna to the particular frequency of the sending station. This may prove to be impossible, if other stations are sending at frequencies of sensibly the same magnitude. It is for this reason that the government has assigned definite frequencies or wave lengths to various stations so that they will not interfere with each other.

The purpose of the detector

If we assume that the sending station shown in the figure is causing the ether to vibrate at a frequency of 1,000,000 cycles per second — 300 meters wave length — the electrons at the receiving station will oscillate at the same frequency, and the strength of the oscillating current will depend upon the elimination of the inductance and capacitance effects by tuning. If a telephone receiver is connected between the antenna and the ground, a current will then oscillate in the winding of the telephone receiver at a frequency of 1,000,000 cycles per second. No sound would be heard in the telephone for two reasons: first, the soft iron diaphragm in the telephone receiver is too heavy to vibrate at such a high frequency; and, second, the human ear would hear nothing if the diaphragm did vibrate at this frequency because the ear does not respond to vibrations above 20,000 per second.

It has been known for more than fifty years that certain mineral crystals will conduct an electric current in only one direction. Many crystal rectifiers have been applied to the problem of wireless reception, notably silicon, zinc oxide,

galena and carborundum. The sharp point of a wire — called a "cat-whisker" — is usually pressed lightly against the crystal and in some instances two different crystals are placed in contact, a piece of chalcopyrite being employed to advantage with the zinc oxide. While such crystal rectifiers are usually called "crystal detectors," the use of the word "detector" in this connection is misleading, since it suggests that such an arrangement responds in some way to the ether vibrations. The fact is that the current in the receiving antenna is allowed to flow in one direction only, so that when the key is pressed at the sending station the vibrating contact shown in the figure interrupts the high frequency antenna current and during each contact the rectified current in the telephone receiver produces a click. Between each interruption of the current in the sending antenna several thousand oscillations take place in the sending and receiving antennas, but the rectifier in the receiving antenna allows the electrons to flow in one direction only so that the receiver diaphragm will be pulled in one direction The clicks heard in the telephone receiver will then be of the same frequency as the vibrating contact at the sending station, and, since this is an audible frequency, the dots and dashes of any code may be sent between the two stations.

The Continental Code is used exclusively in radio telegraphy and will be found fully described and illustrated in the chapter on Communication by Wire.

The electron tube used as a detector

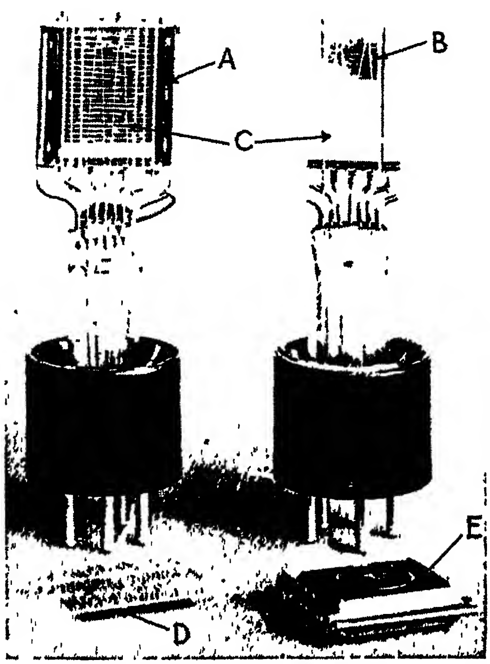
It will be observed that while the crystal detector and telephone receiver may take the place of the original coherer, telegraph sounder and battery, it possesses the disadvantage that the energy which vibrates the diaphragm of the telephone receiver must come from the sending station and is therefore very weak. It is more desirable to have some device at the receiving station which will cause a local battery to send a rectified current through the telephone receiver which will vary in exact accordance with the strength and frequency of the ether vibrations.

In the more sensitive receiving sets this is accomplished by means of an electron tube, a device which has contributed enormously to the success of radio communication. The development of the present form of electron tube was made principally by Dr. Lee De Forest. The tube consists

Courtesy National Broadcasting Co.
THE SMALLEST AND THE LARGEST TUBES USED IN RADIO STATIONS

of an evacuated glass bulb containing three elements: a filament, a grid and a plate. The filament, which is made of tungsten, nickel, or any one of quite a number of alloys especially developed for the purpose, is connected to a storage battery which sends a current through the filament and heats it to incandescence. The rapid in-

ternal vibration of the filament, due to its high temperature, dislodges millions of electrons from the atoms and these electrons form a cloud about the incandescent filament. If the positive terminal of another battery, usually known as the "B" battery, is connected through the telephone receivers to the plate, and the negative terminal is connected to the filament, the plate will be made positive with respect to the filament. It will be remembered that the electrons are negative particles of electricity, and,



A MODERN PENTODE TUBE
A. AND E.—PLATE, B AND D —GRID, C.—FILAMENT

since positive electricity attracts the negative, the electrons will be pulled from the filament to the plate and a steady current will flow in the telephone receivers. This will cause no sound in the telephone receivers since the diaphragm will be bent permanently. If an ether vibration now causes the electrons to oscillate in the antenna wire, the grid will be made alternately positive and negative as the electrons flow in and out of it. When the grid is negative its negative charge will push back the electrons surrounding the filament and decrease the telephone current. When the grid is positive it will assist the plate and pull more electrons away from the filament, thereby increasing the telephone current. A negative grid thus tends to shut off the telephone current, while a positive grid increases it.

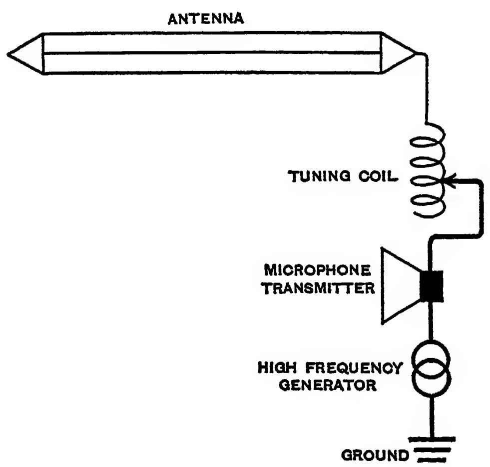
The electron tube will thus serve the same purpose as the crystal detector, and in addition will produce a louder sound in the telephone by alternately applying and suppressing the local "B" battery. Similar tubes may also be used to amplify the sound. If the grid and filament terminal of another tube are substituted for the former telephone receiver terminals, the variations in the grid potential of the second tube will be intensified by the "B" battery. A telephone receiver connected in series with a second "B" battery to the plate of the second tube will thus deliver a much louder sound. The one "B" battery may be made to serve for any number of tubes by a connection which requires the use of an electrical device called a "transformer." The electron tube which has made possible the extensive growth of radio will not only amplify weak signals and detect them but it will also generate and transmit them. At every step from the beginning of a message or a musical program to its final reception an electron tube takes charge.

The electron tube has made possible the vast network of international radio communication.

The radio telephone

In its simplest form a radio telephone sending station will only require the equipment shown in the next figure. With this arrangement the high frequency electric generator will maintain a continuous oscillation of electrons in the antenna wires. The pressure of the sound waves — these are air waves — on the transmitter diaphragm will alternately compress and loosen the carbon granules in the transmitter box so that the resistance of the transmitter will vary in exact accordance with the frequency and strength of the voice. This varying resistance in series with the sending antenna will cause the oscillating current to vary in synchronism with the human voice.

In practice the method of varying the current flowing in a transmitting antenna by means of the human voice or the tones of an orchestra is much more complex. To control the output of a modern high power station by the comparatively weak volume of a solo instrument or of a voice requires a vast amount of amplification. This amplification is supplied by electron tubes.



ESSENTIAL PARTS OF A RADIOPHONE TRANSMITTING STATION

The path over which a program, say from a hotel lobby, gets to the radio listener who may be a thousand miles or more away is as follows: The program is picked up by a microphone somewhat like the one into which a telephone user talks. The weak electric currents from this device are amplified by an electron tube and are then put on a telephone line leading to the broadcasting studio. Here they are amplified again to make up for the loss in power along the telephone line. Then they are put on another line leading to the transmitting station which may be many miles from the studio, probably out in the country away from high buildings which absorb the waves. Here they are given more amplification in larger electron tubes until the currents are strong enough to modulate the output of the transmitter. Then they are flung into the ether through which they speed in all directions with the velocity of light (186,000 miles per second).

At the receiving station very minute currents are picked up by the receiving antenna. By the process of tuning already described the desired signals are separated from all others. Then they are amplified several times and put into an electron tube detector. After detection the signals are audible but still weak. They are again amplified, once more by an electron tube, after which they are strong enough to operate a loud speaker. The radio program is at hand.

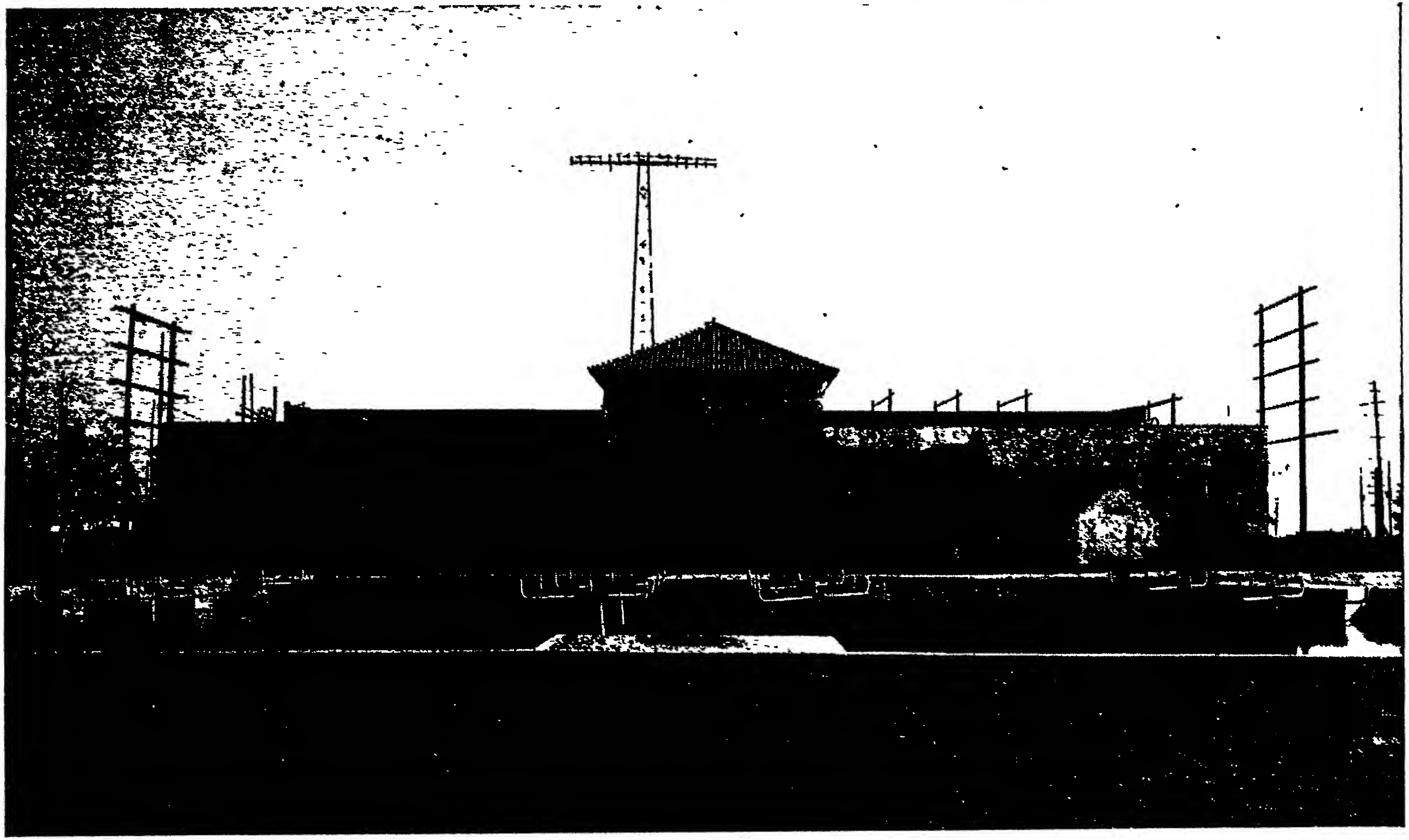
For good reception the transmitting station requires a band of frequencies in the ether twice as great as the highest audio frequency to be transmitted. For example: The highest key on the piano is about 4000 cycles. This means that a broadcast station which wishes to broadcast piano music will require a band width of at least 8000 cycles. Since all broadcast stations are operating in the region between 550,000 cycles (545 meters wave length) and 1,500,000 cycles (200 meters wave length) there are approximately 100 channels each of which is 10,000 cycles wide. There are about 600 stations operating, and because of the paucity of channels many of them must operate on the same band. For this reason interference between stations is very bad in some localities.

The Federal Radio Commission

The rapid growth of the number of broadcast stations all of which originally operated on 360 meters caused widespread dissatisfaction among listeners. Various methods were tried for regulating their mutual interference, but no satisfactory solution was reached until 1927 when the Federal Radio Commission was appointed to issue licenses, govern wave length assignments, and in general to keep the radio structure of the United States in working order. The commissioners, of whom there are five, are appointed by the President and confirmed by the Senate. From its inception the members have been under political pressure which makes the administration of a difficult technical problem even more difficult, but they have managed to build up an admirable system.

In this country the listener pays only in an indirect way for the programs he enjoys

AN OLD AND A NEW COMMERCIAL WIRELESS STATION



Courtesy Radio Corp of America

The first Marconi commercial wireless station in the United States is shown in the right foreground. Above it are the offices, towers, and superstructure of R.C.A. Communications Inc., at the Rocky Point, Long Island, transatlantic sending and receiving station.

— programs which may be of fine music or other entertainment costing many thousands of dollars. In other countries he is taxed for his privilege. In these countries broadcasting is a government monopoly under no necessity of catering to the listeners' desires, the programs are inferior to ours, and are often poorly transmitted. In the United States the Radio Commission renews the licenses of only those stations which can prove that they are capable of transmitting properly programs of high merit.

Short wave communication

The broadcast band is only a small part of the total number of frequencies on which messages can be transmitted by radio. The other parts of the radio spectrum are divided into many services. The very long waves (those from 30,000 meters to 2000 meters) are used for transoceanic communication or for communication between two points, two army posts, for instance, several hundred miles apart. The somewhat shorter waves which lie between 2000 meters and the beginning of the broadcast band are set aside for safety at sea services, compass stations, SOS calls, and ship to shore traffic.

The last decade has seen a remarkable exploitation of the very short waves, those below 200 meters, which in the beginning were thrown away as useless. Amateur operators and experimenters began to play with them and it was not long before they showed that in theory and practice the professionals were wrong when they said that these waves could not be used for transmission because they would be absorbed by trees, houses, etc. The amateurs showed that not only could messages be sent long distances over short waves but that much less power was required than in the long wave stations. To-day the main part of the world's radio messages is carried on waves shorter than 200 meters.

The older long-wave stations used antennas a mile or more in length and required power by the hundreds of kilowatts; these modern short wave stations use antennas fifty feet long or less, and require only tens of watts for equivalent communication service. Furthermore distances half around the world can be covered, even with very low powered apparatus. It is not at all uncommon for the private owner of a short wave transmitter to communicate with other amateurs in a dozen distant countries in the course of an evening. The power needed is less than that required by an electric iron.

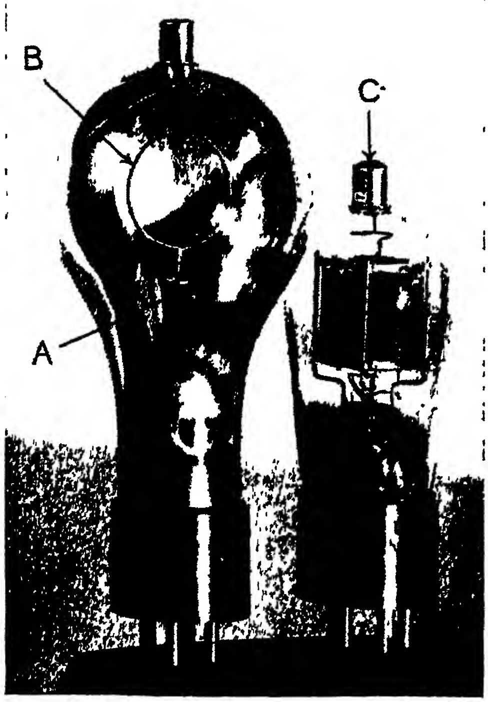
Short waves are used more and more to keep police headquarters in cities in touch with their patrol cars on the streets. The cars carry radio receivers and as soon as a crime is reported to headquarters the officer in charge broadcasts the details, giving instructions to the cars in the vicinity of the crime. The patrol cars speed to the scene, not for a second losing touch with headquarters as they go. Detroit, Washington, Minneapolis, Toledo and Rochester have complete equipment of this type and although the service has been working for only a short time it has proved remarkably efficient.

Short waves have made possible the communication of steamships with home offices, even though they may be half way around the world. Until ships were equipped with short wave apparatus their maximum possible range of communication under the best conditions was about 1000 miles on 600 meters and about 2000 miles on 2000 meters. But on waves as short as forty meters they can now report to their home country from any part of the world, day or night.

Large vessels like the Leviathan carry on radio telephone communication with either side of the Atlantic throughout their voyages. Through arrangements with the telephone companies a passenger on one of these ships can talk to any telephone in the United States or Europe. The first transoceanic service (New York to England) was opened on a single channel at 5000 meters; now much of this important traffic goes on short waves. Other channels carry the human voice to South America and the Orient. This service is available from every telephone in the United States at moderate cost. Business men frequently call their foreign representatives on the telephone to transact important matters.

Nature's radio disturbances

Although it has been suggested at times that some of these unintelligible vibrations may have come from other planets, it is now generally conceded that they are due to oscillating electrons in our own atmosphere. One can always hear the crash of distant lightning at a receiving station, and it is probable that there are many minor electrical discharges taking place in the atmosphere which may only be detected by sensitive wireless apparatus. In



PHOTOELECTRIC TUBE AND VACUUM TUBE

These instruments make sound pictures possible. A. Silvered surface which releases electrons B Ring of metal toward which electrons flow after being released from the surface when it is illuminated by a beam of light C. Grid connection

large cities where many sparks are being produced in the operation of street cars and in the opening of switches, ether vibrations of various degrees of magnitude are to be expected. The principal difficulty from such disturbances is experienced in warm weather and this fact confirms the assumption that most of the so-called "static" is due to electrical discharges between cloud formations.

It may, however, be noted that the continuous hum often heard in the telephone receivers in a building supplied with alternating current for light and power is due to oscillating electrons in the electric wires themselves.

There has probably been no problem in radio communication which has engaged the attention of more inventors than the possibility of eliminating these atmospheric disturbances. Although little has been accomplished in this connection some advantage has been found in the use of coil antennas in place of the more common aerial type. In the coil antenna the ends of a coil of a few turns of wire are connected to the receiving set where the aerial and ground would ordinarily be connected. This coil is usually of square formation with a length of three or four feet on a side. It has been demonstrated that the reception of a coil antenna is best when the plane of the vertical coil points toward the sending station. The signals diminish to zero when the coil is turned 90 degrees from this position.

The advantages obtained by the use of a coil antenna

It will be seen that such an antenna possessing directional receiving properties will not be influenced by atmospheric disturbances coming from a direction perpendicular to the plane of the coil. Now it happens that in Washington, D. C., for example, most of the atmospheric disturbances, for some unaccountable reason, originate in the southwest. A receiving coil antenna with its plane located in the northwest-southeast direction will therefore be quite immune from atmospheric disturbances in Washington.

A coil or loop antenna has other advantages. When it is turned in the direction of the transmitter the signals are louder than at any other angle. If the loop is marked in points of the compass or in degrees, the operator can tell not only from which direction the signals are coming but, if the location of the transmitter is known, he can tell his own position by turning the loop.

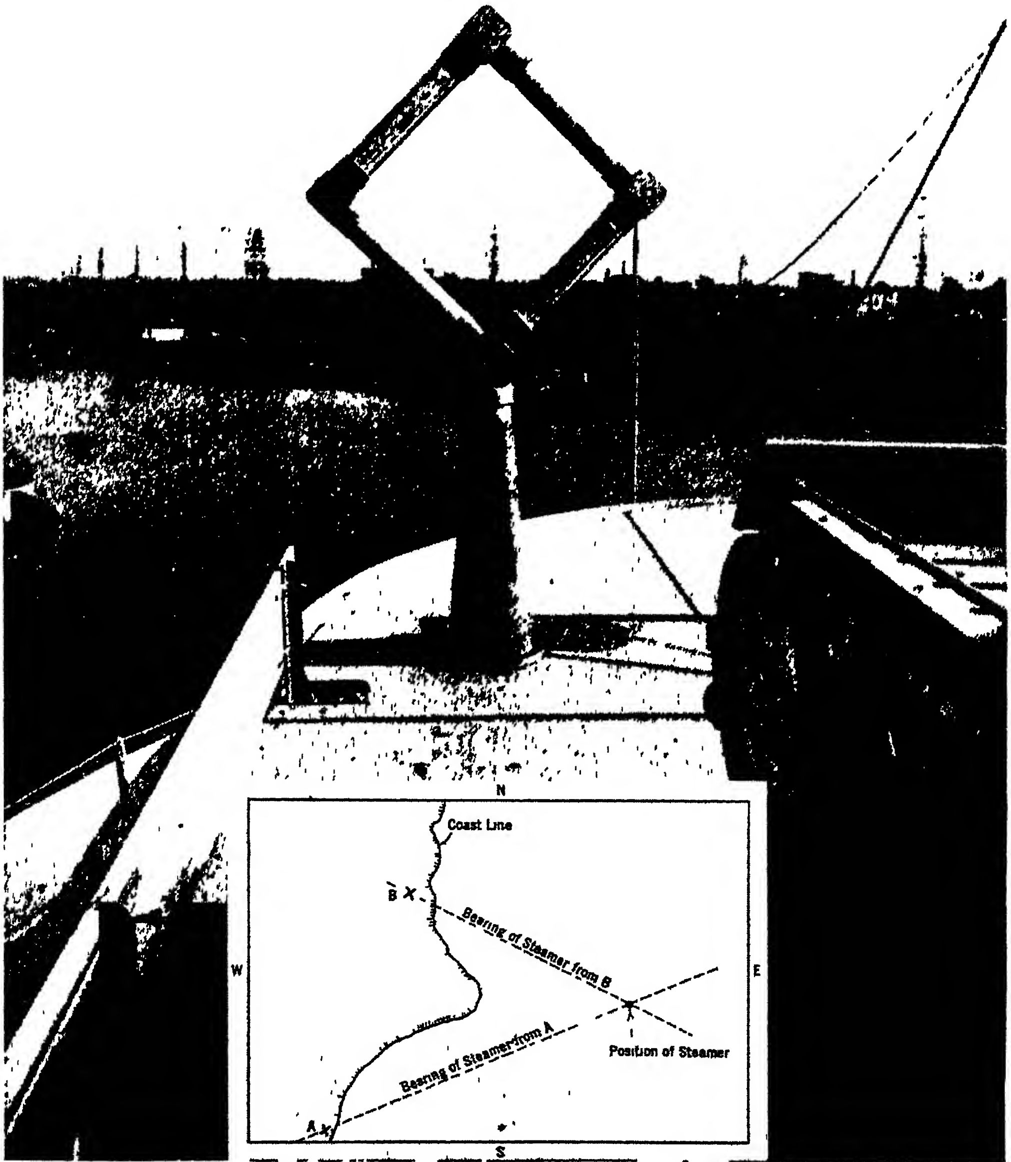
Many stations using such antennas have

RECORDING A TALKING PICTURE IN A STUDIO

Courtesy R.C.A. Photophone Inc.

The microphone which picks up the speech of the players is suspended from the black box hung directly above their heads. The black box is the microphone amplifier from which connections lead to booth B. The actual photographing of the sound impulses of the film is contained in this booth. The camera is located behind the soundproof cloth screen shown in the lower right of the picture.

THE RADIO COMPASS WHICH AIDS MARINERS



Courtesy Radio Corp. of America

Loop of a radio compass installed on top of a Great Lakes ore-carrier. Inside the tubing are the wires of the loop which connect to the radio receiver below decks in the pilot house where the master or wheelsman can make readings. In practice the loop is rotated until signals as heard in the pilot house are loudest. Then the loop is pointing toward the station sending out the signals. In the case above, the transmitting station is somewhere on a line at right angles to the length of the ship.

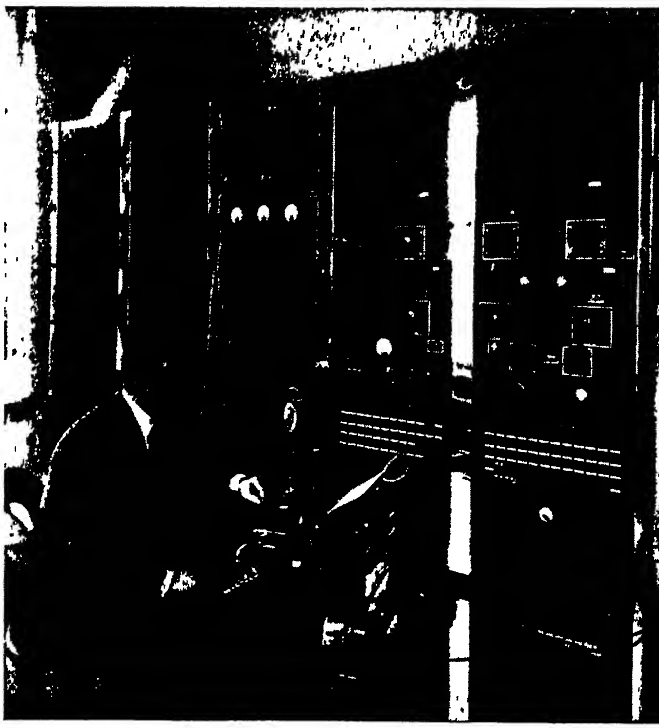
Courtesy of Radio Corp of America

Inside the ship and immediately below the loop is the radio receiver, the handle for turning the loop, and the compass card which the operator reads when signals are loudest This card then gives the direction, in compass degrees, of the transmitting station If two bearings are secured from different stations, the captain will know that his ship is on a line drawn to each of the stations. Where these lines cross is the exact location of his vessel.

been placed along the seacoasts of the world whose purpose is to direct ships at sea, giving them their location with respect to harbors and obstructions. The ship sends out a series of signals, the compass station operator rotates his loop until the signals are loudest. He then reads from his machine the direction of the vessel. If the master of the ship gets several such bearings, he can plot them on his chart and mark his position by their intersection. Hence even in the densest fog, the master of a ship with such equipment aboard can, with the aid of the station on shore, determine his location.

Hundreds of compass stations mechanically operated have been located at mouths of harbors and at points of danger. These send out signals continuously. The radio operator on board the ship, or the master, rotates his loop and determines his bearing from the short station. By getting two or more bearings from other stations, he can plot exactly his location off shore. Compass stations are also placed along standard air routes. In addition to their loop antennas the fliers carry receiving equipment which enables them to get weather reports and apparatus which permits them to talk, either by code or voice, with ground stations, all of which has greatly contributed to the safety of airplane transportation.

The distance to which a wireless message may be transmitted from a sending station of given power to a receiving station with definite facilities for reception depends upon many strange factors. Transmission at night is generally better than during the day, and longer distances are to be expected over water than over land. Transmission from one station to another is invariably poor if the sun is rising or setting in the region between the two stations. Sometimes when the reception of signals is weak with one frequency a change in frequency will bring the signals in strong again.



Courtesy National Broadcasting Co

CONTROL ROOM APPARATUS AT WEAF, BELLMORE, N. Y.

Before the development of short waves the amount of power a station radiated governed its ability to transmit messages a great distance and during bad weather conditions. On the short waves, however, power is less important than a knowledge of what wave length to use on a particular time of day in a particular season of the year to transmit to a station in a particular part of the globe. It is no longer significant to speak of the "world's largest station."

Various applications of radiant energy

The radio-telegraph and radio-telephone have been developed as described to produce either vibrations which may be translated at the receiving station by a definite code of dots and dashes, or the voice may be transmitted directly. The radio-tele-

graph is well established for the transmission of messages overland, to the depths of a mine, overseas, to ships at sea, between ships at sea, to a submerged submarine, or to an airplane in flight. Various applications of automatic telegraph machines have been made to increase the speed of transmission, the message being printed on a paper ribbon as fast as it is received.

It has been demonstrated many times that the dangers of navigation are greatly reduced when vessels are equipped with radio-telegraph apparatus. A ship in distress may give its bearings and call other ships to help. Thousands of lives and much valuable property have already been saved in this way by the use of the radio-telegraph.

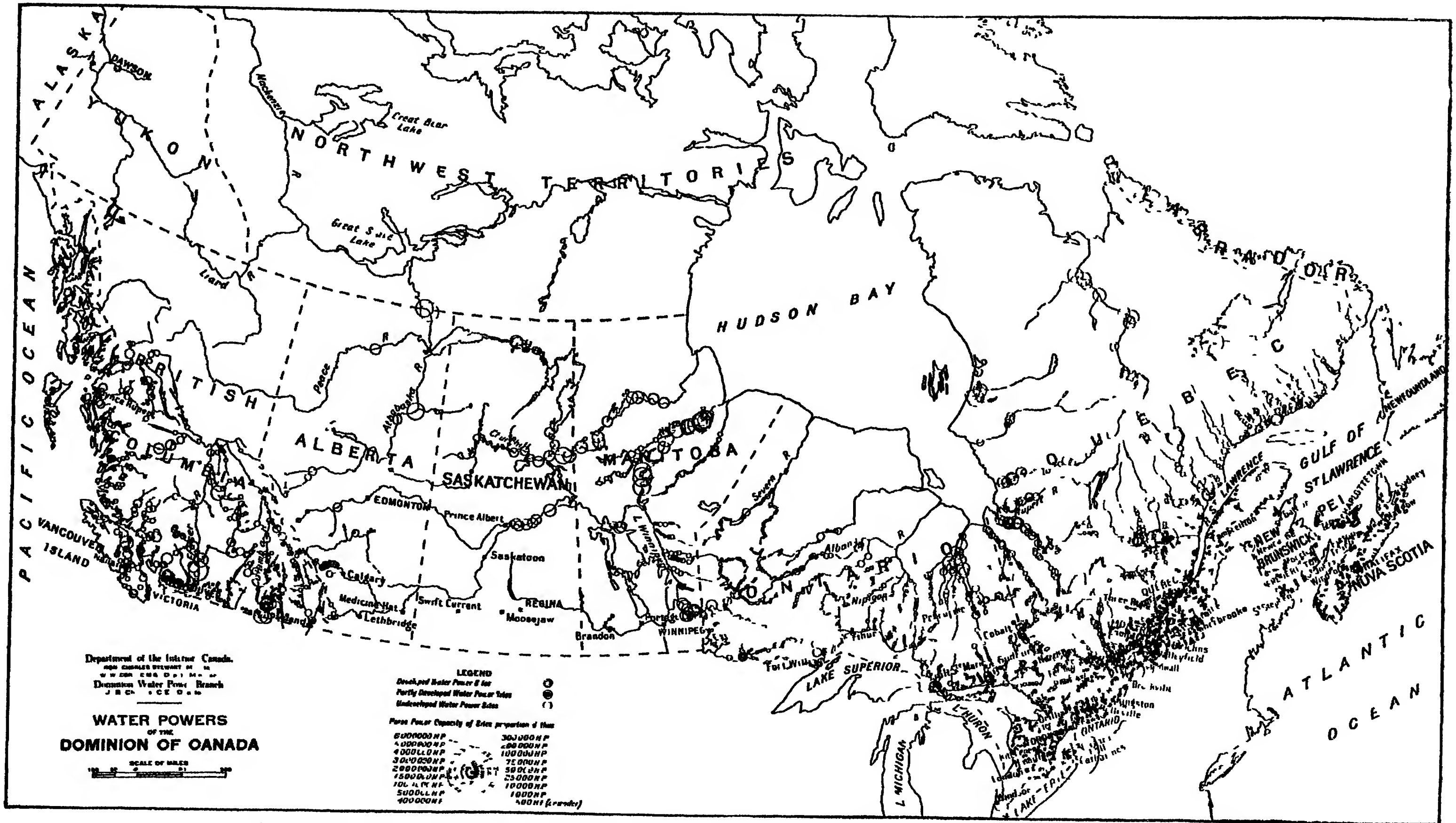
Radio communication has been successfully applied to moving trains particularly in Canada where radio has been relied upon to keep trains in touch with the dispatcher's office. Broadcast programs are picked up in some of the de luxe trains both in Canada and the United States but radio on trains has not attained the widespread use it may enjoy in the future. Radio has also been used to control the movement of mobile objects, battleships or motor cars, from remote points. Such feats are usually in the nature of stunts, but the application in time of emergency may be of importance. The Navy on a number of occasions, from a distant ship or from the shore, has maneuvered battleships by means of radio.

Television in which the receiving station picks up a visual image of what is going on in the transmitting station, will undoubtedly use radio waves as the means of connecting transmitter and receiver. The art of television has not advanced to the stage where satisfactory visual programs can be received. The problem is very complex, and it may never be possible to see, in one's home, distant scenes with the clarity of a moving picture. Enormous sums of money are being spent on television research, however, and program service of a sort is already offered to the public.

Broadcasting has made it possible for the President to sit at his desk and to talk to the entire nation In 1931 the possible number of listeners to an event of national importance was in excess of 50,000,000. There were 15,000,000 receivers in use, and by means of interconnecting telephone lines more than 100 of the nation's broadcast stations could be connected together to transmit the same program. Broadcasts from foreign countries have become a matter of course. The Pope, speaking in Rome is clearly heard in the furthest corner of the United States as well as in almost every other country in the world, again on short waves. Similarly the voice of Lindbergh on his arrival in Tokyo in August, 1931, was sent by short waves to this country and retransmitted by a network of broadcasting stations. International exchange of broadcast programs has taken place on a number of occasions, individuals of world wide prominence speaking from Europe and Asia to this country and vice versa Whether or not television, when as completely developed as radio broadcasting, will enable "sight-casting" to take place simultaneously with the transmission of sounds is as yet speculation and a dream of the future which may not come true.

Other uses of electron tubes

The electron tube invented by De Forest which made modern radio communication possible has been found to possess other uses in addition to its enormous value in communication. In fact an entire new science has developed based on the ability of the electron tube to amplify, detect, and generate oscillations. This art is called "electronics" and uses the tube to control moving machinery, open and close doors without touching them, start and stop trains, count and sort objects in process of manufacture and do hundreds of other important industrial functions. In connection with the "electric eye", the photoelectric tube which gives off electrons when illuminated by a beam of light, the electron tube brought the sound moving pictures into an industry that was almost defunct and revived it almost over night. Engineers believe that a new technical era may be built up about these two electronic tubes.



DEVELOPED, UNDEVELOPED AND PARTIALLY DEVELOPED WATER-POWER IN THE DOMINION OF CANADA

OUR WATER AND FOREST WEALTH

The Conservation of these Material Bases of our Future National Industrial Progress

THE PRESENT AND THE FUTURE PROBLEM

IN discussing the nation's mineral wealth we found that, to prevent the impairment of our heritage, public policy must look with clear-sighted vision into the future. Private enterprise sometimes thinks too largely of immediate profits, and the competitive system is apt to operate with an insufficient regard for future resources When we come to our riches in forest and water, we find similar need of looking ahead. First of all, let us consider our water supplies

Water is the chief constituent both of animal and of organic tissue, and both plants and animals require water to an amount exceeding greatly their own volume A man of one hundred and fifty pounds has been found to digest over a ton of water each year; animals, including man, are indeed four-fifths water In the making of a bushel of corn there is required twenty-two tons of water. To produce a ton of clover requires five hundred and seventy-six tons of water, a pound of beef from fifteen to thirty tons.

Water is then so important a constituent of plants and animals that it can reasonably be called the principal limiting factor of life. What is it that differentiates the United States east of the ninety-fifth meridian from the western parts? Primarily this: The eastern part possesses an average yearly rainfall of forty-eight inches, the western much less than thirty inches. West of the one hundred and third meridian, the rainfall over large regions is less than twelve inches. A scarcity of rainfall has made almost a third of the country a semi-arid zone, has withdrawn from some forms of human utilization a territory larger than Great Britain, Germany, France, Spain, Portugal, Italy, Poland and Denmark combined.

The problem of conserving our material resources is vastly different in regard to water from what it is in regard to the minerals. In the case of minerals it is primarily a question of abstention, of substituting wherever economically feasible some non-mineral material. But the water supply renews itself constantly, the rain which falls upon land, the snow which gathers in banks and glaciers, must sooner or later, whether in a day or in the course of hundreds of years, return to the ocean and be again available for evaporation and precipitation. The water supply, being perpetually renewed, should then be utilized fully; wherever possible it should be substituted for other materials.

The sole source of our fresh water is, of course, the rainfall, including the snow and hail. Each average year there falls upon the surface of the United States 215,000,000,000,000 cubic feet of water. This huge mass equals the volume of ten Mississippi rivers. Of this total rainfall about one-half, technically called "the fly-off," is evaporated. A sixth is consumed in plant growth or chemical combinations or permeates into the deeper strata of the earth. This is known as "the cut-off." The remaining one-third, "the run-off," flows through our rivers and water channels into the sea. Thus the entire yearly rainfall becomes available to man either as the fly-off, the cut-off or the run-off. We shall consider each of these separately.

The "fly-off," indirectly useful to plant life by furthering precipitation

The fly-off passes directly into the atmosphere without direct use either by man or plants. But it is not without utility, for by being passed into the atmosphere it is added to the quantity of moisture received directly from the ocean, and thus furthers precipitation. Where the atmosphere is dry, evaporation proceeds at the most rapid rate. Arid regions are thus at a double disadvantage, for of the rain which they receive, a larger part must needs escape into the atmosphere. Where the surface of the ground is porous rather than hard, the amount of the fly-off is also lessened by reason of capillary action This principle is utilized by the dry farmer, who, immediately after a rain, seeks to prevent the escape of the moisture by plowing, and thus breaks up the capillary openings of the surface Evaporation is also retarded by an abundant vegetation.

The "cut-off," an indispensable source of water supply for man and beast

The water which does not escape through the rivers or by evaporation, becomes the underground water. By this the earth's salts are dissolved and made available for plant life. This water, once absorbed by the roots of plants is conducted through the trunks of trees and bodies of plants and finally transpired into the atmosphere. In arid regions it is the lack of this water below the surface which limits vegetation. As many plants grow as can find water; and the plants which do live are the abstemious water users, such as the cacti on alkali soil.

That part of the cut-off which is not transpired into the air by means of plants is lodged temporarily in the soil as ground water.

This water permeates the cracks and the openings of rocks down to a depth at which no cracks are to be found. The amount of water below the subsurface is immense. W. J. McGee, of the U. S. Inland Water Commission, has estimated that it is equal to the entire rainfall of the United States in seven years.

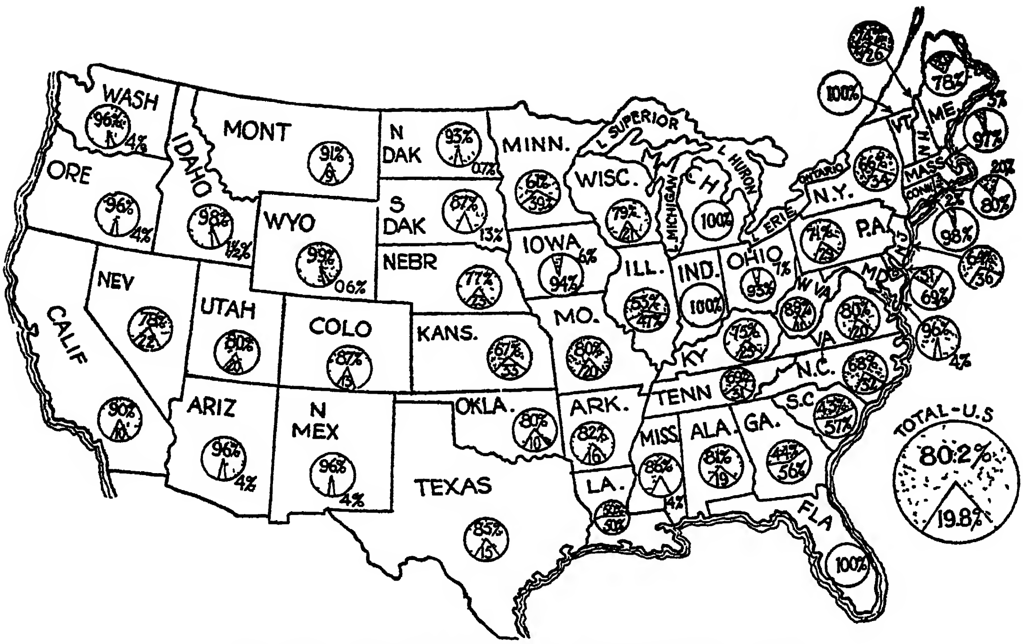
The underground water may be made available to man by natural springs or by boring and sinking wells McGee states that in this way the water supply of animals and of four-fifths of our population is obtained. The cut-off is thus indispensable, and it is highly necessary that the depth be not greatly lowered at which the underground reservoir can be reached But by deforestation and injudicious farming the amount of water reaching the sea by the cut-off has been greatly increased McGee estimates that in the upland regions of the eastern United States the water table has been lowered fully ten feet, so that many brooks and springs and three-fourths of the shallower wells have gone dry. The risk of a crop loss by drought has been increased, and the waste through the Mississippi enlarged by 15 per cent. We have been using our underground water much like our natural gas — we are taking from the ground more than is restored

To lessen the escape through rivers, western states have recently begun to employ various devices. Across the Santa Anna River a concrete headgate has been built, so that in time of a flood the water is spread over the alluvial cones and thus passed into the soil Much can also be accomplished by covering the earth with vegetation and by cultivating so as to leave the surface rough.

The "run-off" which supplies water for domestic use, power, irrigation, navigation

The run-off of the United States amounts annually to 70,000,000,000 cubic feet One-third of this escapes to the ocean by the Mississippi alone. The run-off may be utilized by man for the following purposes: first, for the domestic water supply; second, for water-power; third, for irrigation; lastly, for navigation. In this chapter space will permit us to discuss only the first two of these

The most important of these uses is, of course, to furnish the domestic water supply. Fully $2,000,000,000 is now invested in waterworks in the United States. Indeed, this is one of the wonders of modern civilization.



USED AND UNUSED WATER-POWER IN THE UNITED STATES

To our savage predecessors obliged to descend a canyon and gather the trickling water in a jar, or make a long trip to a spring, how marvelous would it appear to see the present city dweller gather water anywhere by merely turning a faucet

Prior to the age of the industrial revolution, water was the principal motive force used by man. Indeed, until toward the end of the eighteenth century, only water and, to a lesser degree, wind were utilized in industrial establishments. Mechanical power was then, however, confined largely to milling and to very small factories. It was not until the age of coal that there was any noticeable lessening in the use of man power. But today the productivity of factories depends less than at any former period upon human power. Man has become a director and a distributor rather than a mere producer of power. And in recent years there has been a decided turning to the earlier source — to the use of water as a mechanical power.

A special investigation made by the Bureau of the Census in 1912, covering 5221 central electric light and power stations, discovered that of the 7,530,000 total horse-power employed, 2,470,000, or practically a third, was developed by water-wheels. Over nine-tenths of the water-power was used by 225 large hydro-electric stations, each of which reported water-power of over 1000 horse-power. Since 1912 the creation of hydro-electric power has proceeded even more rapidly than before. It is true that the use of steam and gas has also grown remarkably, but we must remember that the knowledge of how to render water-power available at any considerable distance from the place at which it is generated is largely a recent discovery The possibilities of water-power have only recently been unfolded, but its increasing use in the future is certain.

In an earlier chapter it was shown how conclusively industrial leadership depends upon cheap mechanical energy, and how this country's recent tremendous strides have been largely due to its remarkably large supplies of cheap coal. We cannot be at all certain, however, how long the United States can hold its relative advantage in fuel-power, great as that advantage is. Many authorities have stated that at the present rate of increase in consumption all our coal will be gone before the middle of the next century.

And who can tell to what extent the coal resources of the United States will be drawn upon by the rest of the world as the European reserves approach depletion and as South America and Africa — lands of little coal — support denser populations? If it be true, as Leighton asserts, that one-third of the coal now used could be saved by the wise utilization of water-power, too much emphasis cannot be placed upon the necessity of developing these "white coal" resources.

It is often predicted that the future will witness the development of other sources of power which will render less important our coal and our water. For instance, the wind may be still further utilized, and it may become economically feasible to harness by motors the direct energy of the sun. Be this as it may, the direct utilization of the wind and sun possesses difficulties insuperable under our present knowledge. We cannot wisely risk our national future upon improbable or at least uncertain discoveries.

Apparently insuperable difficulties in the use of suggested alternatives

For extensive use, wind possesses the irremediable defect of being extremely variable. Storage batteries may be developed to hold power for periods when the wind does not blow; but this can be accomplished only at a relatively great expense. Neither is the sun available as a continuous source of energy, for half of each day the sun does not appear. For the present the use of sun-motors belongs only to the field of physical research.

As the price of coal rises, the cheapness of water-power must yield it the advantage even over coal for large installations. And not only this, but electrical energy generated by water possesses the advantage over all others, not only in its cleanliness, but also in its capacity for ready subdivision. It may be carried cheaply to the small factory, the farm, or the home. Already it is furnishing the energy for many household purposes; by the mere pressing of a button it is available for cooking, for cleaning floors, for running sewing machines.

By its use in small factories a check may be given to the present tendency for industry to concentrate in large establishments. At least the fuel advantage of the large firm may be neutralized. Used by means of small motors directly attached to the machines which they propel, electrical power obviates the enormous waste of energy that would otherwise be consumed in driving the heavy belts and shafting used in power transmission as shown in our chapter on that subject.

Principal obstacle in the way of water-power competing with coal

What now are the conditions necessary to the most complete utilization of water-power? The main requirements are nearness of the site to the market, and a uniform flow. The expense of electrical power transmission has in the past been its principal obstacle in competing with coal. But recent discoveries have widened the field so that now, even in regions of cheap coal, transmission for several hundred miles is commercially feasible. A 200-mile radius opens up an area of 120,000 square miles. If the site be so located in a dear coal district that 300-mile transmission is possible, an area can be supplied of 270,000 square miles. As our factories have gone to cheap coal in the past, so in the future they must go to districts of cheap and readily available water-power. Science, too, is rapidly expanding the areas over which electric power may be transmitted without undue loss.

Second of the two requirements necessary for complete utilization of water-power

The other requirement was that of a steady flow. The unsteadiness of the flows of our streams has been scarcely comprehended by many. In some districts the larger part of the rainfall occurs in a few months of the year; in fact the greater part of the precipitation may be due to a single large storm. Even where the rainfall is equally distributed, streams may have a very uneven flow. The problem of equalizing the flow is, then, the principal difficulty of water-power.

Some streams possess natural reservoirs which insure an even flow. For instance, the Niagara possesses an immense storage basin, so that the maximum flow is never more that 35 per cent above the minimum. And the Deschutes of Oregon is known as the "river that never changes" But such naturally favored sites are few, and it is necessary to rely chiefly upon artificially constructed reservoirs In the region of the upper Mississippi, on the headwaters of the Wisconsin and the Miami, and in the northeastern parts of the United States, much money has recently been spent on such reservoirs. Reservoirs alone, however, are insufficient. In regions where deforestation has taken place, great quantities of silt are brought down in flood times, thus rapidly filling up the reservoirs. It is therefore necessary that at the headwaters of the streams forests be preserved to equalize the stream flow.

Water is available to produce more than six times the power now utilized

With the extension of the field of electric power transmission, it becomes necessary to inquire as to the extent of our undeveloped water-power resources In an estimate made by the U. S. Geological Survey, issued in 1921, the minimum potential water-power of the country was put at 28,000,000 horse-power This estimate assumes that storage reservoirs are not used; the minimum horse-power is that obtainable at minimum flow If storage is used, so that the average rather than the minimum flow would be available, the estimate is that the potential water-power of the country is at least 54,000,000 horse-power For Canada, the comparable estimates of the Dominion Water Power Branch of the Department of the Interior are: minimum, 18,000,000 horse-power, maximum, 32,000,000 horse-power. The capacity of the water-wheels at present installed in the United States is hardly more than 10,000,000 horse-power, and the present Canadian installations afford less than 3,000,000 horse-power. What a magnificent prospect this holds for industrial North America!

Industrial leadership, both past and future, depends on mechanical energy

The secret of industrial leadership will in the future, even more than in the past, depend upon mechanical energy Since water bids fair to become the most important source of energy, the question of its control assumes daily added importance. Some have even regretted that governments ever surrendered to private hands the title to coal lands. After these resources are once developed as legitimate fields of private ownership, the problem of recovering them for public use, even if that were desirable, becomes exceedingly difficult Vested interests, the rights of property originally acquired without restriction, may not altogether be ignored. The proper time for the assertion of public rights is *before* rights of private ownership are created.

Already there has been a considerable concentration of the private ownership of water-powers In 1909, Herbert Knox Smith, Commissioner of Corporations, reported that 35 per cent of the horse-power then utilized was controlled by a relatively small group of proprietors And the water-power sites so utilized were the strategic sites, holding the advantage over others by reason of their nearness to markets and the adequacy of their stream flow. Further delay in the assertion of public control can only mean the building up of legitimate private property rights which may, perhaps, stand in the way of the larger interests of power conservation.

Advantages of public control of natural water-power sites

What now are the advantages of public control? First of all, such control is necessary in order to secure for the public reasonable charges. He who controls mechanical energy controls its price. The monopolizing of natural water-power sites means that the public cannot always rely upon the competition of private firms to secure reasonable prices. Public regulation, of some sort, is the only alternative. State control is also necessary to secure the full development of water-power sites.

In many parts of the country water-power sites have been held for purely speculative purposes and are not being devoted to immediate use Moreover, private parties may establish dams here and there in such a way as to interfere with the plans of others Public interest demands that before franchises be given for dam construction the assent of competent government engineers be obtained

Old English law of riparian rights

The old law of riparian rights, which we inherited from England, gives to the adjoining owners full rights to the flow that occurs past their holdings When water-power was used almost exclusively for milling purposes, this law was not grossly out of harmony with public interest But today the use of water-power has completely transcended former bounds, and the old law is a fetter binding enterprises conducted for the public interest. When cities wish to acquire power for lighting or other municipal purposes, they are forced to pay the private owner millions of dollars in damages for water-powers unused and undeveloped. Thus a free gift of nature must sometimes be paid for before the public has a right to utilize its advantages. This method of obtaining water-power rights is unduly expensive. The country from which we inherited our law of riparian rights is today not hampered in this way. An English city may build a water reservoir and, without purchase of water rights, may turn from the stream enough water to maintain unimpaired the "low water" power. In this way both public and private interests are subserved.

Provision for federal and state control of water-power rights

By the terms of the federal constitution, Congress is given the right to regulate interstate commerce, and this involves control over streams used for purposes of navigation. In the future it is likely that the public interest in water will be much more important from the standpoint of power than that of navigation; but this control of navigation involves to a certain extent regulation of water-power rights. For instance, in 1906, an act was passed by which the Chief of Engineers was given power to impose such control upon the construction of dams over navigable rivers as are necessary "to protect the present and the future interests of the United States" By a series of other acts, the government itself has begun the construction of dams and is leasing, for limited periods of time only, water rights to private corporations Finally, the Secretary of the Interior has withdrawn from private entry districts holding possibilities of future water-power development.

In many of the states the public control has been assumed in a manner directly in contravention of the old English common law For instance, the state of Washington, by its constitution of 1889, enacted "The use of the waters of the state for irrigation, mining, and manufacturing purposes shall be deemed a public use." The constitution of North Dakota, adopted in 1899, reads "All flowing streams and natural water courses shall forever remain the property of the state for mining, irrigating, and manufacturing purposes." Similar provisions may be found in other state constitutions.

President Roosevelt on the importance of safe-guarding our water-power resources

The assertion in this manner of public water rights is to be most vigorously commended. As President Roosevelt stated in 1909: "Our water-power alone, if fully developed and wisely used, is probably sufficient for our present transportation, industrial, municipal, and domestic needs. Most of it is undeveloped and is still in national or state control. To give away, without conditions, this, one of the greatest of our resources, would be an act of folly. If we are guilty of it, our children will be forced to pay an annual return upon a capitalization based upon the highest prices which the 'traffic will bear.' They will find themselves face to face with powerful interests, intrenched behind the doctrine of 'vested rights,' and strengthened by every defense which money can buy and the ingenuity of able corporation lawyers can devise."

Our forest wealth and the indirect utilities subserved by forests

Let us now consider our forest wealth. The general public has only recently begun even to comprehend the enormous value of our wooded tracts. The annual value of the forest products of the United States is over $2,000,000,000, and the industries which subsist wholly or mainly upon wood yield employment to more than a million and a half of workers. But the services of our forests can by no means be measured solely by the value of the wood products; and it is the recognition of this fact which has brought the question of forest care to the forefront in the conservation problem.

The indirect utilities subserved by forests are many and great. It has already been shown how greatly forests tend to prevent the dissipation of water into the run-off. The forest floor has often been likened to a blanket, and a blanket will hold more moisture than the porous soil of treeless tracts Because of its roots and undergrowth, the forest encourages the absorption into the underground reservoir which furnishes the water for wells, and from which springs and streams are fed. Mention has also been made of how forests check the frequency of floods and regulate the flow of streams. Indeed, in the absence of forests, reservoirs, either natural or artificial, often become useless through the washing in of great quantities of silt. It has been found, too, that a forest moderates the extremes of temperature. Its presence retards the melting of snow in the spring Snowbanks in the forest remain until late in the summer. From them little rivulets trickle, carefully and gradually feeding the streams.

The relation of forests to the soil

The relation of forests to the soil is well set forth in the report of the National Conservation Commission: "That forests hold soil and that hillsides denuded of forest do not hold their soil is to be seen in any mountain region in the United States. One small stream has been found by actual measurement to deposit silt in one year equal to one and one-half tons per acre of its watershed. For the whole United States the loss of soil each year is from one to two thousand million tons. At the lowest estimate the total quantity of silt carried by our streams would cover one foot deep a surface of more than 900 square miles. The larger part of it is deposited in the lower courses of our streams and in our harbors, a menace to navigation and to present developed water powers, and a handicap to their development."

The Commission also states that in the national forests in the Rocky Mountain and Pacific Coast states, 12 per cent of the cattle and 21 per cent of the sheep of these states find summer ranges. And in the southern pine belt and southern mountains sheep, cattle and hogs are granged for the larger part of the year. And the value of game whose existence depends upon the conservation of the forests should not be underestimated. Most of our furs are taken from forest animals. Yearly we export raw furs valued at from $29,000,000 to $33,000,000, and larger amounts are held for domestic manufacture. Few fresh-water fish can live in streams fed from denuded water-sheds, and those which do so exist are mainly of inferior value.

The five great forest regions of the United States and their extent

Such are a few of the services rendered by the forests. What now is the extent of our resources? Originally the forests of the United States contained timber surpassing in quantity and variety that of any other area of similar size in the world. There were five great forest regions — the northern, the southern, the central, the Rocky Mountain and the Pacific. The northern was the home of the white pine and other hardwoods, red pine, spruce, hemlock, cedar and balsam fir. This tract, stretching from Maine to Minnesota, originally covered 150,000,000 acres. The southern forest extended along the Gulf and South Atlantic states, from Texas to New Jersey. Here grew yellow pines, in the swamps cypress, and on the better soils hardwoods. This district covered 220,000,000 acres.

The central forest, stretching northward from Texas to eastern Iowa, and thence to the Atlantic, was the hardwood area Here grew the oak, the yellow poplar, elms, hickory, chestnut, red gum, ash and walnut. This extended over an area of 280,000,000 acres. The Rocky Mountain forest was largely made up of coniferous mountain-growing trees, such as western yellow and white pine, larch, spruce and other firs. In the Pacific forest of the coast grew the evergreens, including the splendid Douglas fir and the redwood, the sugar pine, and other firs, cedars and spruces. This covered an area of 90,000,000 acres. Neither history nor geology has recorded another area where the trees were so large or the stands so heavy. Altogether the original forests covered 820,000,000 acres, with a stand which, according to present measurements, would amount to more than 5,900,000,000,000 board feet. This was our "forest primeval."

What remnants of our former forest splendor are left today untouched

What have we today? Except in the Rocky Mountain and the Pacific areas forests are now mere remnants of their original splendor. The stand of board feet has, by clearing for agriculture, by fires and logging, been reduced over one-half; the forest acreage has been lessened by 350,000,000 acres. Our yearly consumption is three and one-half times as great as the yearly growth, and we export more lumber than we import. Particularly large has been the destruction of the rarer and better grades, woods which in some cases require centuries to mature. In 1928 yellow pine lumber cost 130 per cent more than in 1904, white pine 100 per cent more, walnut 200 per cent more. The extinction of many of the hardwood grades is already threatened.

It is not difficult to explain this unprecedented destruction of our timber resources. In colonial days the forest was the enemy of the settler. It retarded his agriculture, and therein lurked wild animals and hostile savages. Wood was the superfluous commodity; cleared land rare. The woodsman could not fail to sink his ax into the tree with a feeling of malicious satisfaction But industrial progress has meant an increasing consumption of wood, so that today the problem is not to clear the forests away, but rather to lessen the timber waste.

Wasteful cutting, wasteful manufacture, fire and pest among the causes of loss

What are these wastes? First of all, there is the loss incurred through careless cutting. On our private forest lands an average of 25 per cent of the timber is left standing or wasted in the woods. That this loss can be greatly reduced is shown by experience on our national forests where, by the introduction of methods common in other countries, such wastes have been reduced 10 per cent. Part of the present waste is unavoidable under present conditions. Nevertheless, there are many ways by which the waste can be reduced without the impairment of present profit and with the security of permanent gain. First of all, immature trees should be saved. The poor grades of lumber come from the small trees, and on the basis of their values a few years hence, only a loss is incurred by cutting them. Clean work in the woods is also necessary. Trees are often left in the woods which, though defective in some respects, are nevertheless merchantable. High stumps and broken trees may be used for pulp. When left in the forest this requires the cutting of expensive trees. There have been further avoidable losses through the failure to care for young growth It costs no more to fell trees uphill than to let them roll downhill, and it is not exceedingly expensive to release young trees bent over by the weight of those fallen. Sufficient seed trees should be left. In the northwest, extensive areas, formerly heavily timbered with white pine, have, because of the cutting of seed trees, no second stand. The cut should, furthermore, not be limited to the choicest timber, but the mature trees and, particularly, those of inferior varieties, should be cut to make way for the younger and more valuable species.

There are also avoidable losses in milling and manufacture, a general failure to utilize by-products carefully Science is now just beginning to acquaint the public with proper methods of battling with insect pests, and unwise and heavy taxation has necessitated the too rapid cutting of the trees. But in the reduction of fire losses particular progress is to be made. Yearly since 1870 the toll of the forest fire has averaged $50,000,000. And this figure scarcely represents the total loss, for the young growth destroyed is worth far more than the merchantable timber Fires also encourage the growth of poorer woods, for the hardier and the more valuable varieties are usually the most combustible. But fires do not confine their ravages to the destruction of the timber. They also burn the humus of the soil After a fire, especially in areas previously run over, there is left little organic material.

Much has been accomplished in the control of fires, but much more yet remains to be done. Nothing but perpetual vigilance can solve the problem. In each of the great national forests, patrol systems have been established, committing the timber to as regular surveillance as the streets of our cities. Fire lanes are necessary.

Despite all the precautions, fires are bound to spread beyond control. The problem is then to confine it within narrow limits Nature requires a century and a half to produce the white cedar and the tamarack in the northern swamps, for western hemlock one hundred and thirty years, for beech one hundred years, for white oak eighty years This is too long a period for private enterprise, which thinks primarily in terms of immediate profit But the government, which is stable and enduring, can well undertake the work of preserving these future necessities of industry.

In 1891 Congress awoke to the necessity of invoking its legislative powers to prevent the rapid destruction of the timber resources In that year it was enacted that "the President of the United States may, from time to time, set apart and reserve, in any state or territory having public land bearing forests, in any part of the public lands wholly or in part covered with timber or undergrowth, whether of commercial value or not, as public reservations, and the President shall, by proclamation, declare the establishment of such reservations and limits thereof" And in 1897 a Bureau of Forestry was established in the Department of Agriculture.

Photo by courtesy of U S Forest Service

FOREST SERVICE LOOKOUT STATION ON TOP OF MT. EDDY, CALIFORNIA

Withdrawal of lands more valuable for timber than agriculture in recent years

Under the provisions of the law of 1891 lands esteemed more valuable for timber than for agriculture have been withdrawn from time to time: under Harrison's administration over 13,000,000 acres, under Cleveland's 25,000,000, under McKinley's 7,000,000, under Roosevelt's 148,000,000. When Roosevelt retired from office in 1909 the larger part of the forest areas in the public domain of the Pacific and the mountain states had thus come to be held by the government in the interests of the general public. Since then boundaries have been increased as well as more carefully adjusted, so that now there are over 175,000,000 acres within the national forest boundaries, over 150,000,000 of which are, in the narrower sense, "national forest land." All of our large western rivers have their origin within the national forests. Altogether these forests cover an area nearly as large as that of the thirteen original states — and a fifth larger than the area of France.

Wisdom of these withdrawals practically shown already in several ways

In many ways the wisdom of these withdrawals has been exemplified. At a comparatively insignificant cost a system of fire protection has been established which has reduced fire losses to 3 per cent those on private holdings. During the period of governmental protection the use of the forests by the people has been more than doubled. The quantity of timber cut each year could at least be doubled with comparative safety.

The states have also seriously begun the task of building up their forest reserves. In 1929 there were 12,580,368 acres of state forests, also 726,577 acres of municipal and county forests and parks. But most of the forest area is still under private ownership, and it is probable that the amount of standing timber on the public reserves is only one-fifth that on private. The problem of timber conservation cannot, therefore, be solved unless some method is adopted to reach the private owner.

State cutting laws and other regulations of private forestry recently passed

In several states laws have now been passed prescribing specified rules for cutting and otherwise regulating private forestry. In Louisiana a bill was introduced to the legislature in 1908 prohibiting the cutting of any tree less than twelve inches in diameter. It is further provided that brush must be removed from the neighborhood of young trees. In other states similar bills have met the approval of the legislatures and the courts have, in general, favorably interpreted their constitutionality. For instance, the supreme court of Maine has decided that the state has a constitutional right to require forest owners to handle their property in such a manner as not to jeopardize the public's interests.

The difficulty of enforcing silvicultural measures, however just

But, however admirable the spirit in which such silvicultural measures have been passed, their enforcement must be decidedly difficult. An army of forest inspectors would be required. It is likely that such measures would often be couched in terms inapplicable to local conditions. When such is the case, great antagonism is likely to be invoked against the law. It is probable that more is to be accomplished by endeavoring to arouse the private owner's *interest* in the proper care for his timber.

A standing crop harvested once in a generation or once in a century cannot justly be taxed as heavily as though it were a crop harvested annually. Unwise taxation laws, laws which make necessary rapid cutting, have much to answer for, and should be abolished. There should be the utmost coöperation between private owners and state foresters. Much can be accomplished by disseminating a scientific knowledge of forestry. We must, in short, whole-heartedly accept the principle that our forests are a national heritage. Each successive generation holds them, with the right of use, as trustee for the future.

FROM CAVE TO SKYSCRAPER

The Triumph of the Modern Engineer
and Scientist over Space and Matter

THE WONDERS OF REINFORCED CONCRETE

PRIMEVAL man sought refuge from the elements and marauding beasts in a cave. In this he displayed no more intelligence than did the animals themselves for they did the same. Later he began to shape rough shelters from any materials at hand. As society developed men congregated into tribes and finally there came into existence great nations in which a few were rich and powerful and the rest very poor, mostly slaves. The rich did not have to be contented with buildings which were merely shelters and commenced to erect elaborate structures as temples to their gods or enduring monuments to their own greatness. For these reasons the Egyptians built their pyramids, the Greeks their Parthenon, the Arabs the Alhambra and the medieval Europeans their cathedrals.

Up to this time all building materials, with the exception of terra cotta products obtained by burning clay, were used as nature supplied them, but with the development of industries in England large buildings became necessary not as monuments or temples but as factories, and new materials gradually came into use in their construction. In 1801, cast-iron columns and beams were used in building a fireproof cotton mill in Manchester; and by the middle of the nineteenth century, girders and columns of iron were in general use in England for supporting the floors of mills and factories. All this was a step in the right direction; but unfortunately there was no master builder in the civilized world with the genius necessary to make fine use of the new materials.

The French, it is true, showed some originality, and boldly used only iron in some churches and municipal buildings in Paris. But among them there was no Michael Angelo or Leonardo da Vinci ready to seize the opportunity for creating a new and authentic style It was left for the American engineer to use his brain in the development of building materials and their efficient use.

There are Americans living today who spent their childhood in a log cabin roughly chinked with mud. In the short span of a human life we have so advanced in the science of building that today we can, with a small force of men, in a time measured in months, erect a majestic structure such as ancient builders with limitless slave labor at their command could never have dreamed of building. How has this been accomplished? Not by increased skill — workmen today are no more skilful than those of old — but entirely by the ingenuity and inventive genius of the scientist and of the engineer.

The marvelous result is the modern skyscraper, a wonder of rapid engineering development, built of steel and stone, tile or concrete; fireproof, sanitary and enduring. No monarch has erected these as temples, or monuments of his greatness; they are entirely the outcome of economic conditions in our great cities, they are the monuments of an industrious race which has fearlessly met and overcome its difficulties. A great volume of business had to be transacted in districts of limited area, and requiring at the same time large floor space which had to be provided on a comparatively small space of ground.

Buildings of old type of construction were out of the question as the thickness of the lower walls became prohibitive when the building was of any considerable height American ingenuity broke away from old traditions entirely and confidently struck out in a new and unexplored field. Inspired wholly by the spirit of Chicago and New York the American architect made monstrous structures by setting upright a steel bridge and plastering it with stone, terra cotta or concrete

A CONCRETE BUILDING THAT HAS LASTED NINETEEN CENTURIES, THE PANTHEON, ROME

In both conception and execution, the skyscraper is original. It manifests the best qualities, as well as the worst defects, of the American mind. Probably we are too near present-day work to fully understand it, but we may be sure that whether we will or not, our architecture is a record of our progress and our thoughts. Whether it shall record our best aspirations depends by no means solely upon our architects, but upon the development of an appreciative interest on the part of cultured people generally, and especially of our leaders in thought and action.

In the architecture of ancient Egypt, one sees reflected some of the aspects of nature and many of the characteristics of the people, which remained unchanged for centuries And this monotonous, massive treatment of their architectural works only confirms our knowledge of the Egyptians gained from other sources.

The Greeks delighted in contrasts, like that of decorative with plain surfaces, and of minor variations in detail. The Romans cared more for the effect gained by repetition of motive; the mind is not excited to an active artistic delight but is impressed with a vague sense of sublimity. An interior like that of the Pantheon, with its simple divisions, its surfaces so sparingly broken, its immense dome brooding equally over all, conveys a sublime idea of unity, which is perfectly expressive of the racial character of the ancient Romans.

Roman architecture is more flexible and practical than the Greek and is thus more nearly adaptable to modern requirements. Still, while the bigness, the grandeur and the dignity easily arouse our admiration, there is about it a uniformity, even monotony, to which modern culture will not submit.

Undoubtedly the American skyscraper is a remarkable work of industrial science The highest at present is the Woolworth Building, which reaches a height of 792 feet above the pavement It is arranged in sixty floors, with non-stop elevator service to the upper stories. It contains 30,000 tons of steel, and its height from the foundation is 905 feet. The Singer Building is 815 feet from the foundation, with 10,000 tons of steel work in it, but it only rises 612 feet above the pavement The Equitable Building rises but 485 feet from the street, though it occupies an entire block. The Municipal Building is 700 feet high.

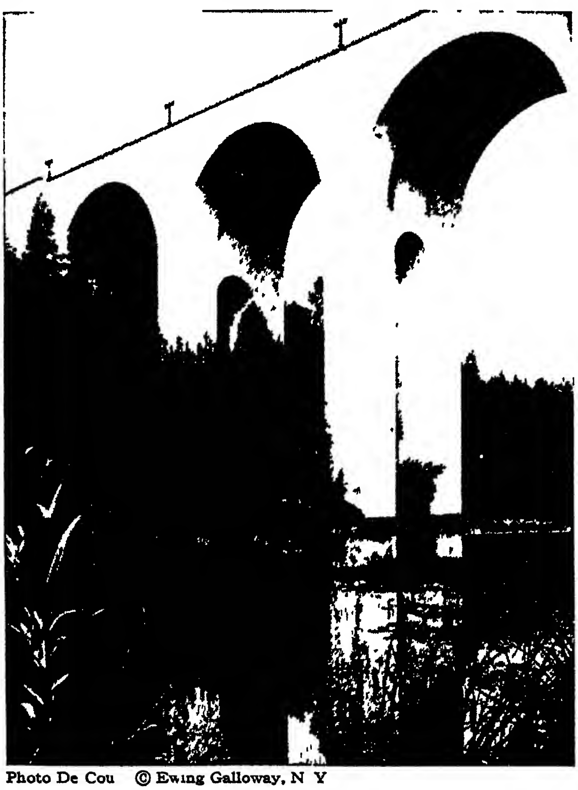


Photo De Cou © Ewing Galloway, N Y

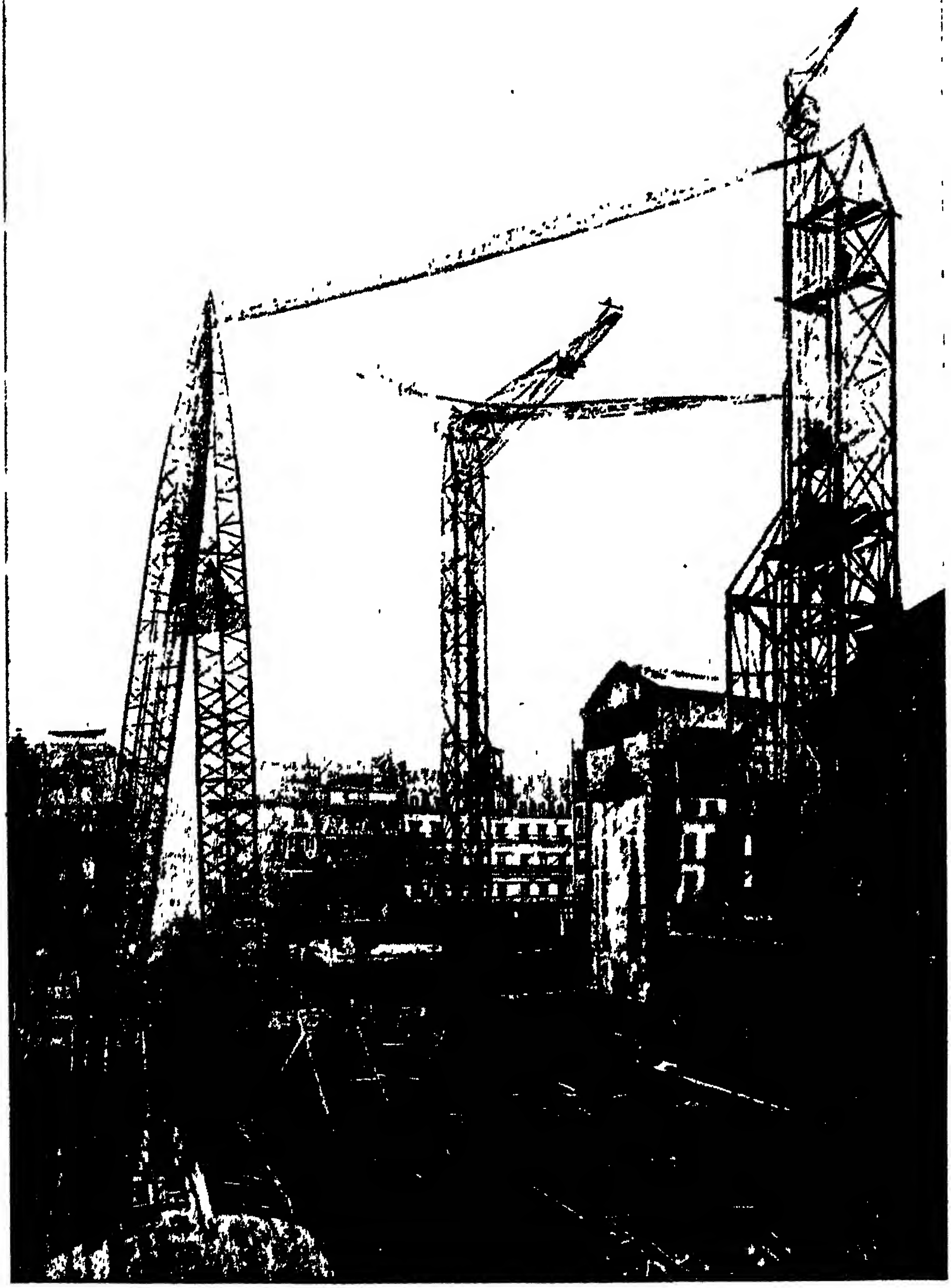
A CONCRETE STRUCTURE OF THE PRESENT DAY

The impressive Punte Cabrille, San Diego. The seams in every arch are to allow for contraction and expansion.

There seems no reason why such steel buildings should not reach 2000 feet; for this height is possible under the building regulations of a number of cities, which merely limit the weight of structures to fifteen tons per square foot of foundation. Steel is now cheap and strong enough to enable an architect to frame a system of columns and beams and girders which would spread over a fairly large foundation the weight of an edifice double the height of the Woolworth Building.

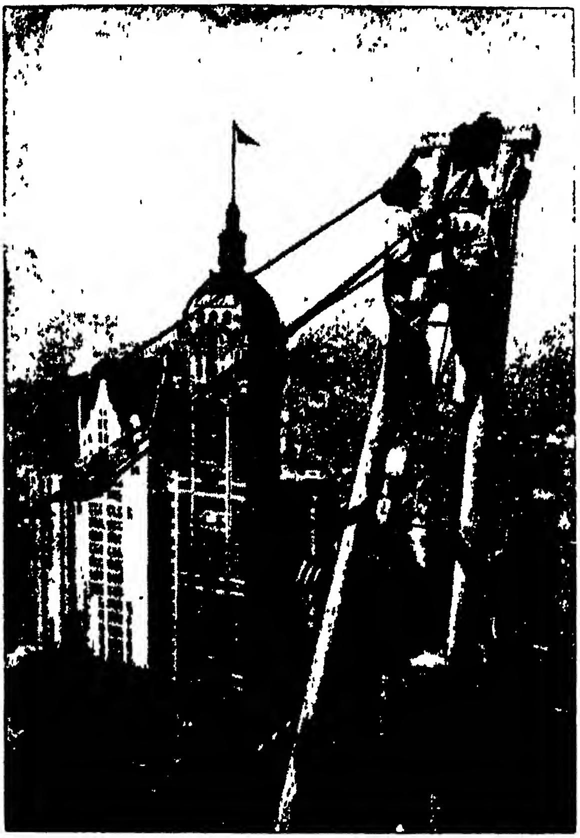
Perhaps, however, nature is not so easy-going as the building authorities. The skyscraper architect has surmounted many difficulties In the marshy land of Chicago he floats his immense structures on rafts; in New York he tunnels down to the rock, or sinks huge walls of cement to keep the shifting soil in its place. A series of disastrous fires has taught him that steel becomes one of the weakest of building materials long before it grows red-hot So he now cases in all his columns, girders, and beams with some fairly fireproof substance.

But, having done all this, he has still to face the same difficulty as the engineer who builds a bridge of steel or iron; or, rather, he has to face the same difficulty under more perilous conditions He has to fight against the wind. In very strong gales the pressure that the wind exerts is enormous. The earth has a dragging effect on the wind, so that its force greatly increases with its height from the ground From bridge experiments it appears that a wind pressure of fifteen pounds to the square foot at a height of 50 feet may be increased to a pressure of sixty-five pounds a square foot at a height of 380 feet. In tornadoes, such as at St. Louis in 1896, pressures of forty-five to ninety must have been reached, judging from the stability of buildings overturned. The larger the surface the stronger the pressure which the wind exerts on every square inch.



The many-storied structures of today are built by huge cranes set up on lofty derricks. The cranes lift from the ground all the steel girders, and lower them into their exact positions, where riveters await them ready to bolt them into place. This method does away with the use of much costly scaffolding.

In present practice a wind pressure of thirty pounds to the square foot is usually provided against. The steel skeleton consists of three chief parts: columns, girders and beams. The columns are continuous, and designed to offer easy connection of the girders; and on the rigidity of the connections depends the resistance of the building to wind pressure The girders are bolted with hot rivets to the columns; and sometimes a stiffening piece of steel, called a knee-brace, is used to strengthen the structure and carry the wind pressures from the girders to the foundation. In the new Municipal Building, New York, many of the steel girders are five tons in weight; they are the principal horizontal parts, and they are riveted to powerful columns, and across them is laid a network of steel beams The entire design is very simple: it is usually termed a steel cage, and it looks exactly like it. The walls of stone do not hold up anything: they are merely weather shields — curtains that will keep out the wind and the wet.



WORKING ON TOP OF A NEW SKYSCRAPER

A skyscraper in course of construction is an interesting sight. Work that would have taken an army of slaves weeks to perform under the lash in the days when the Pharaohs were building their pyramids is done in a few minutes by the monster cranes which overhang the building. Girders which have required a team of twenty horses to drag to the scene of operation are swung high up into the air by a finger touch on a lever, and then lowered exactly on to the columns, ready for the riveters to bolt down. It took only sixteen months to put up the steel work of the Metropolitan Life Building, with its fifty stories. Clothing the outside walls with marble took a little over three more. In the latest methods of steel-cage construction the stonework is started in the center of the building One gang of men works upwards, and another gang works downwards. In this way the clothing of the walls is done in half the ordinary time, for double the number of men can be employed when the work is begun from the center.

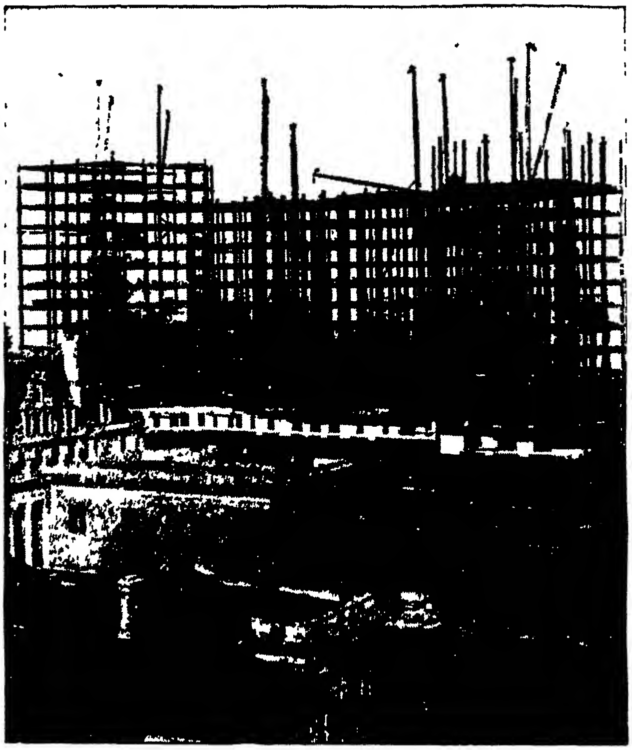
Quickness is everything in the construction of an American skyscraper, and the owners are willing to pay high for all appliances and methods which expedite the work. Every day's delay means an enormous loss of rent and a waste of ground-rent and capital. This is the main reason why the skyscraper of steel is likely still to flourish in America, for no other type of construction permits of so rapid erection; by properly encasing the steel in fire-resisting materials it can be made fireproof; the steel columns being strong in tension as well as in compression are well fitted to resist the overturning force of the wind and the construction being light does not require excessive foundation area, which is a large element of the cost.

THE CITY'S PROGRESS SKYWARD

PLACING IN POSITION AND RIVETING TOGETHER THE STEEL GIRDERS OF A SKYSCRAPER

As it is, the skyscrapers of New York have made the financial center of that city one of the most impressive places on earth Beautiful the scene is not, but it has life and character, and it touches the imagination in a way that no streets of meaninglessly imitative buildings can do. In the titanic cliff-like ranges of steel-built towers is embodied a fierce wild energy of a living kind. The huge buildings have a real grandeur, the grandeur of explosive, lawless, vehement strength In them is expressed the freest and most savage individualism ever existent on the earth, an inventiveness born of need, a triumphant manifestation of the vast unregulated forces which have been working throughout the civilized world since the age of the industrial revolution.

The modern tall building is a marvel of up-to-date scientific appliances. Without scientific engineering such buildings could not be constructed, nor could they be maintained or rendered habitable. It is only necessary to contrast a European building with a typical American building to realize the extent to which applied science dominates the latter. One has only to call to mind his travels abroad, his experiences with "lifts" that lift up but not down, with plumbing without back air-vents, and recall the huge porcelain stoves pointed to with pride as marvels of heating and ventilating apparatus, to realize American building progress. The comforts and conveniences that the American accepts as a matter of course are all very new, very recent, and are not to be found in the most marvelous chateaux in France or the most attractive Venetian palaces In skilful building construction and marvelously convenient appurtenances, America leads the world.

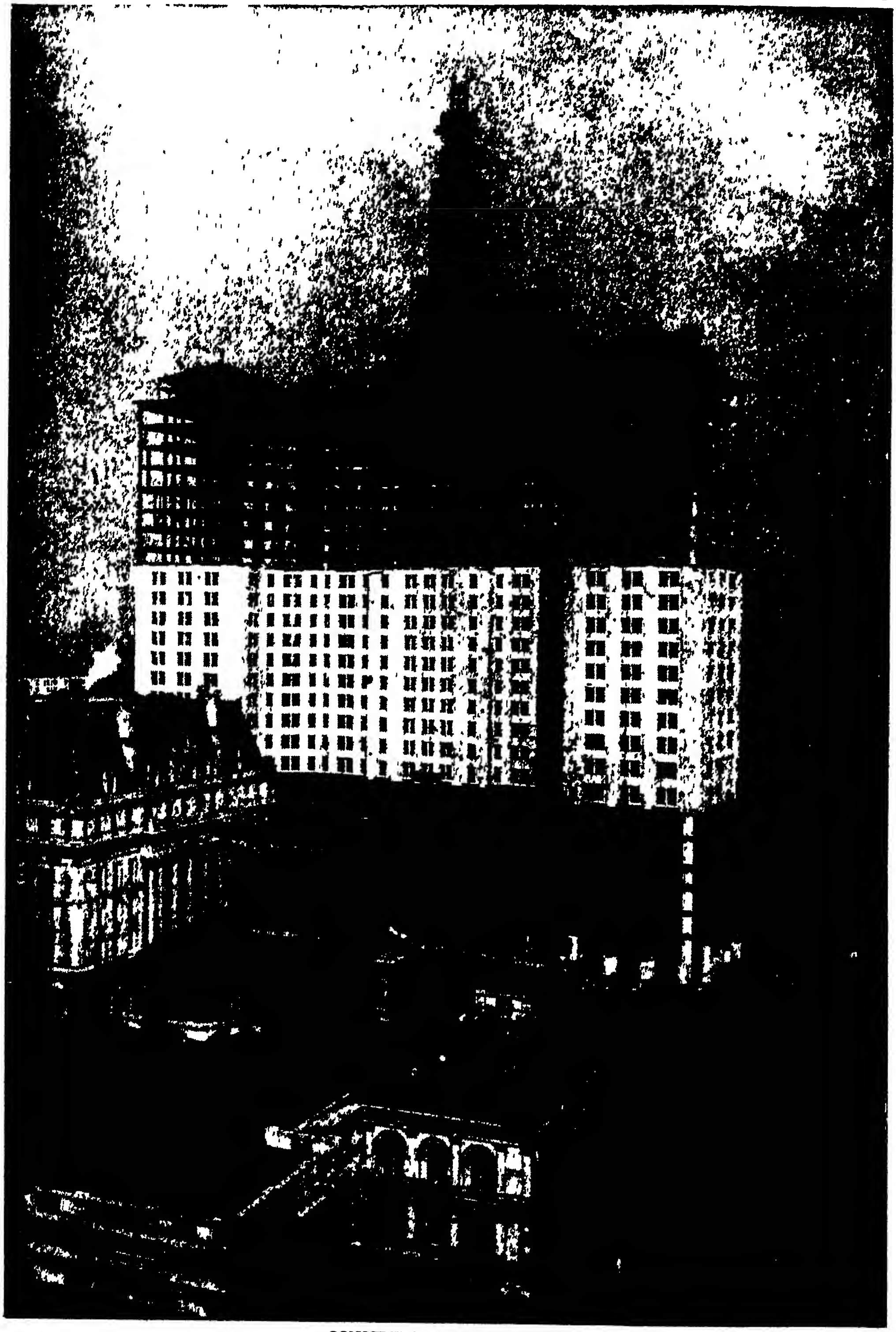


STARTING THE STONEWORK IN THE CENTER OF THE MUNICIPAL BUILDING IN NEW YORK

People have been attracted to the larger office buildings, hotels and apartment-houses, not so much because they are large or high, as because of the superior excellence of their appointments and conveniences and the guarantee of safety from fire which they give. In a large office building or hotel properly designed with the steel frame fireproofed with baked clay or concrete, one is safer on an upper floor than in an old style three to five story building, the air at the level of the upper floors is pure, and since flies are rarely encountered above the tenth floor of a building this nuisance of the summer days and nights is happily avoided.

There have been great developments recently along the line of construction with reinforced concrete. This material can be made absolutely fireproof, practically waterproof and when properly erected becomes stronger and stronger as time goes on. Undoubtedly it has a great future in connection with many types of construction. It will probably never replace the steel-frame skyscraper because of the handicap of its weight, but for factories, warehouses, bridges, dwellings, etc., it has many points in its favor.

HALF-BUILT HOME OF CITY FATHERS



CONSTRUCTION UNDER WAY

It will be noted that the stone facing, begun in the middle, is being carried up and down simultaneously.

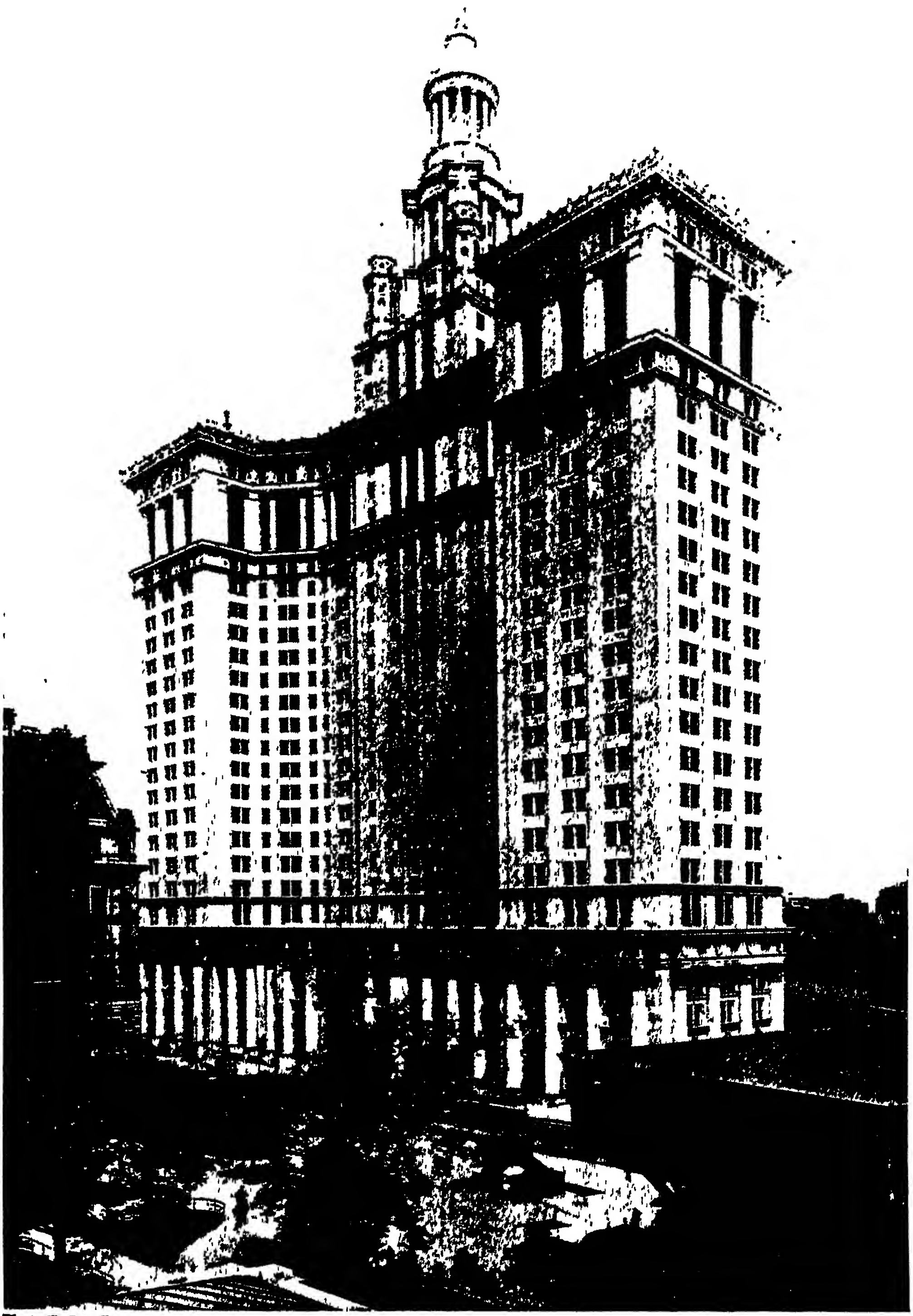


Photo E Stopff

THE STRUCTURE COMPLETE

The Municipal Building of the City of New York is a fine example of public business edifice.

Buildings constructed of reinforced concrete are fireproof, vermin proof, easily cleaned and the walls resist the entrance of moisture, heat and cold. Concrete is impervious to the weather, thus eliminating the cost of painting, and, considering its lasting qualities, it is low in price.

Reinforced concrete is formed of Portland cement mixed with sand, and run into wooden molds. The manner in which a concrete building is erected is more ingenious and wonderful even than steel-cage construction. First of all, the wood is built up into huge hollow pillars and great horizontal beams which are also hollow. Rows of wooden struts are placed under the beams as additional support. Then, in the hollow wooden molds, thinnish rods and pieces of steel are inserted; and, after this, the concrete is poured into the molds. Walls are built up by pouring concrete between two layers of wood; and floors and roofs are made by building up horizontal molds of wood, and making a sort of upper pavement of concrete in them. When all the concrete is thoroughly dry, every piece of wood is removed, and scraped and cleaned and soaped for use on a new building.

Builders in concrete have an enormous expense at the beginning. Their wooden molds have to be quite waterproof, and strong enough to resist the pressure of the concrete. They are made, however, in standard shapes, with a view to economy in taking down rather than cheapness in putting up. This means that they can be used over and over again in the erection of various buildings. They are fashioned somewhat on the lines of steel-cage work.

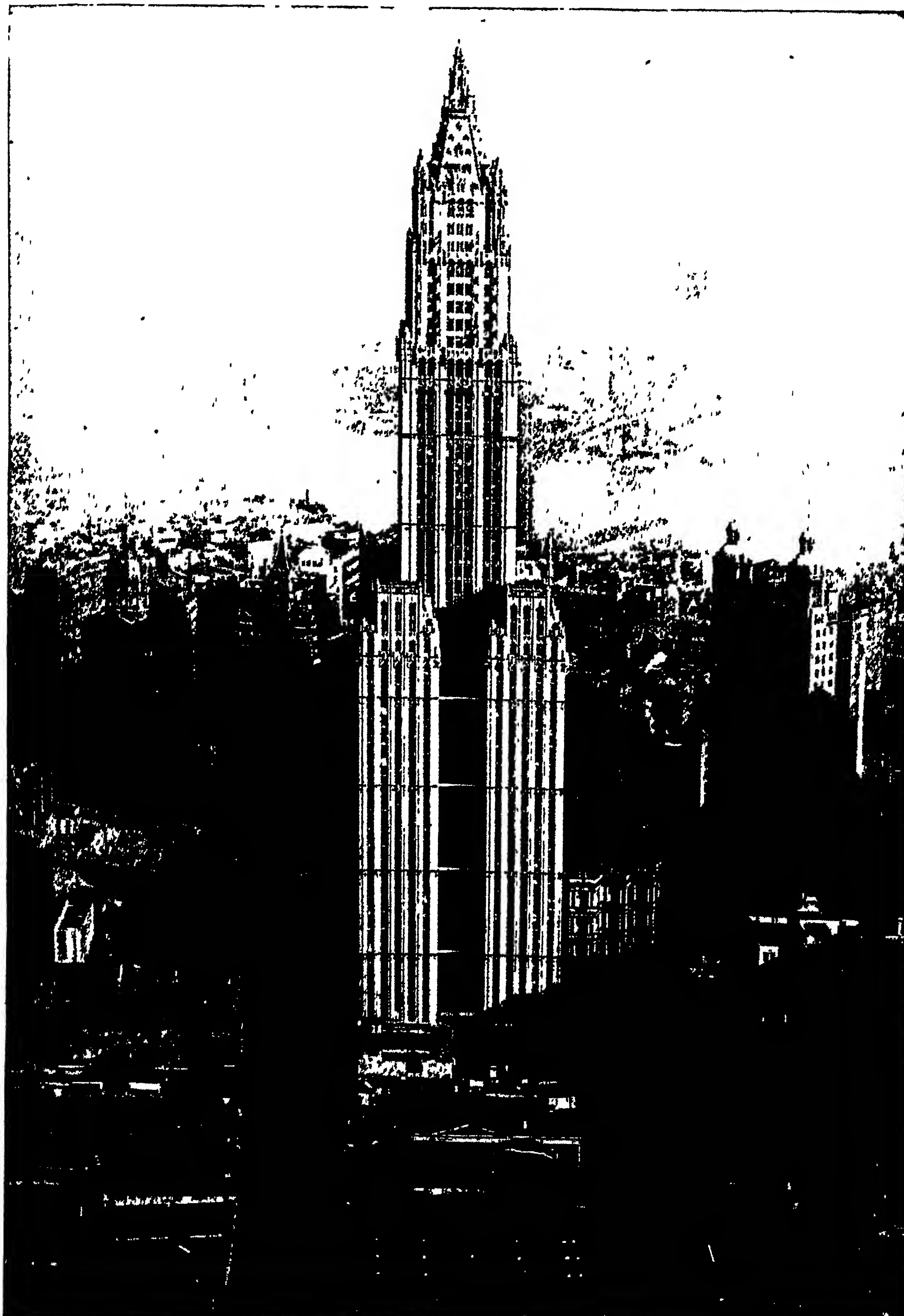
There are special molds for columns, and molds for the girders that rest on columns, molds for the beams that rest on the girders, and solid wooden struts which are placed under all the horizontal molds. Many of the molds are very large and heavy, and they are lifted into place by a giant crane which hangs over the building. Pins serve to rivet the intricate system of molds together. When the pins are drawn out they leave holes in the concrete, which are filled in by hand.

In concrete work the carpenter and the designer of carpentry are the men of importance. The design requires, of course, the highest engineering skill All the stresses have to be worked out, and the amount of steel and concrete carefully estimated, and a good margin of safety allowed for unforeseen accidents. It is not difficult to design a concrete building which will fall down, especially if the wooden molds are removed before the sand and cement are thoroughly hardened. But if the design is good, and the material well mixed and well dried, a building of reinforced concrete is stronger than any design of a similar kind made in stone, brick or other material.

The famous cement with which the Romans built works that still survive the wear of time is weak stuff when compared with modern cement. Portland cement was invented by Joseph Aspdin, a bricklayer born at Leeds in 1811, and so called because of its resemblance, when set, to the then well-known building limestone quarried at Portland Isle, England. In the original process, three parts of white chalk are mixed with one part of clay or river mud. These materials are placed in a wash-mill, where revolving cutters reduce the watery mixture to a cream. This is put in a reservoir to settle, and afterwards dried on hot iron plates, and then burned in kilns and ground to a powder.

Such cement is now often made of limestone and clay in a rotary kiln, or steel cylinder, which may be 12 feet in diameter, and 250 feet in length. The process is continuous in operation, the raw material being fed in at one end and discharged at the other end a finished product. During the passage of the material down the cylinder, perfect calcination is obtained by the injection of coal-dust by means of an air blast. The clinker is cooled and reduced to fine powder in a heavy iron mill. The strength of the cement depends on the fineness to which it is ground; from 90 to 96 per cent of it ought to pass through a sieve containing ten thousand meshes to the square inch. Marl and clay, limestone and slate, can be used to make the mixture.

ONE OF THE WORLD'S TALLEST BUILDINGS



© Major Hamilton Maxwell, N. Y.

THE WOOLWORTH BUILDING AS SEEN FROM AN AIRPLANE

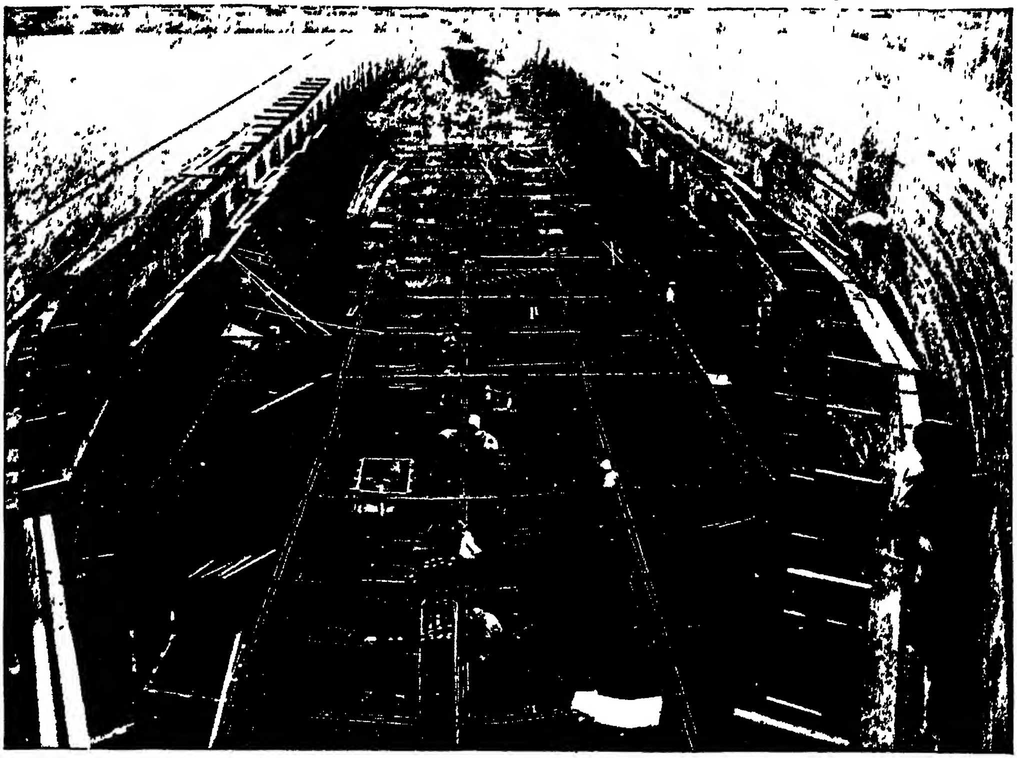
Like Roman cement, which is a natural mixture of lime and clay, Portland cement has the valuable property of hardening in a short time under either air or water. But while concrete made of Roman cement has only a tensile strength of thirty pounds and a crushing strength of two hundred pounds to the square inch, modern cement has a tensile strength of two hundred pounds, and a crushing strength of a thousand pounds. It came into use about the middle of the nineteenth century, and at first there were numerous failures with it. As late as 1887, it was too imperfect for building docks, and objects made of it sometimes crumbled to pieces in twenty years. Even at the present day, it is necessary thoroughly to test the fineness of the cement used in concrete buildings. It is the best of materials when well made, and the worst when the grinding is not perfect. Good concrete has a unique quality: it grows stronger with age.

All concrete, however, has one serious disadvantage. It is good for columns, but bad for beams; it will resist compression, but it gives way under tension. Its resistance to tension is only one-tenth of its resistance to compression. So for many years it was used only in building dams, retaining walls and foundations. A six-inch wall of concrete will cost less than a twelve-inch wall of brickwork, and will be stronger, more durable and damp-proof and fireproof. In short, concrete is the most desirable of building materials, if it were not for its small tensile strength.

LOADING BUCKETS FROM THE CONCRETE MIXING PLANT AT GATUN, CANAL ZONE

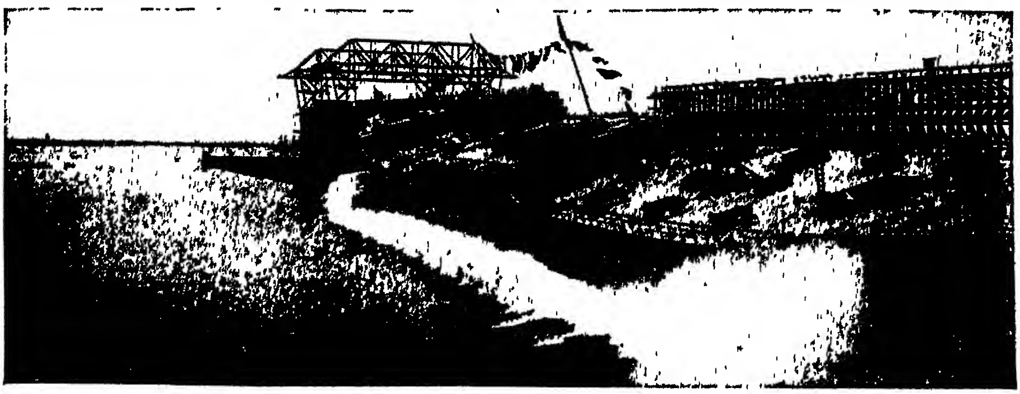
The Romans got over the difficulty by reinforcing their concrete. In the center of the slab they placed bronze rods, crossing each other, but more often they strengthened their coarse material with tiles. By this means the master-builders of the ancient world were able to erect structures of concrete which have withstood the stress and weathering of two thousand years. We began to recover their secret in 1824, when Joseph Aspdin invented the new cement. Then, in 1854, Wilkinson made fireproof concrete floors, in which were embedded iron bars that took the tensile stresses.

THE AGE OF STONE COME AGAIN



BUILDING

FINISHED



LAUNCHED

Concrete steamship *Selma* built during the Great War in record time for the United States government at Mobile (Alabama) Concrete Shipyard by Fred. T. Ley & Co., Incorporated.

With the cheapening in price of steel the value of the new material became generally recognized. Several men of science went thoroughly into the question of the distribution of stresses, and in 1897 a Frenchman, Hennebique, introduced a system of reinforced concrete, by means of which there could be made small beams of very great strength. At the present day there is quite a multitude of systems of reinforced concrete construction and it is difficult to say which is the best. In all of them, steel rods, sometimes straight, sometimes crooked or fitted with angular side-pieces, are placed in the center of a wooden mold, and surrounded with a mixture of cement and sand.

Concrete and steel go very well together; they have an adherence of a hundred pounds to the inch, and they are equal in their expansion under heat. All experience shows that reinforced concrete is immune from bad atmospheric effects. The embedded metal is, moreover, thoroughly protected from corrosion and from fire. Thus it is superior to steel for the erection of bridges, as, instead of requiring constant attention and continual repair, it improves in strength for thousands of years. It has the additional advantage of being cheaper in first cost. Then, in comparison with steel-cage construction, reinforced concrete gives more security against wind-pressure, besides being much more nearly fire and damp-proof.

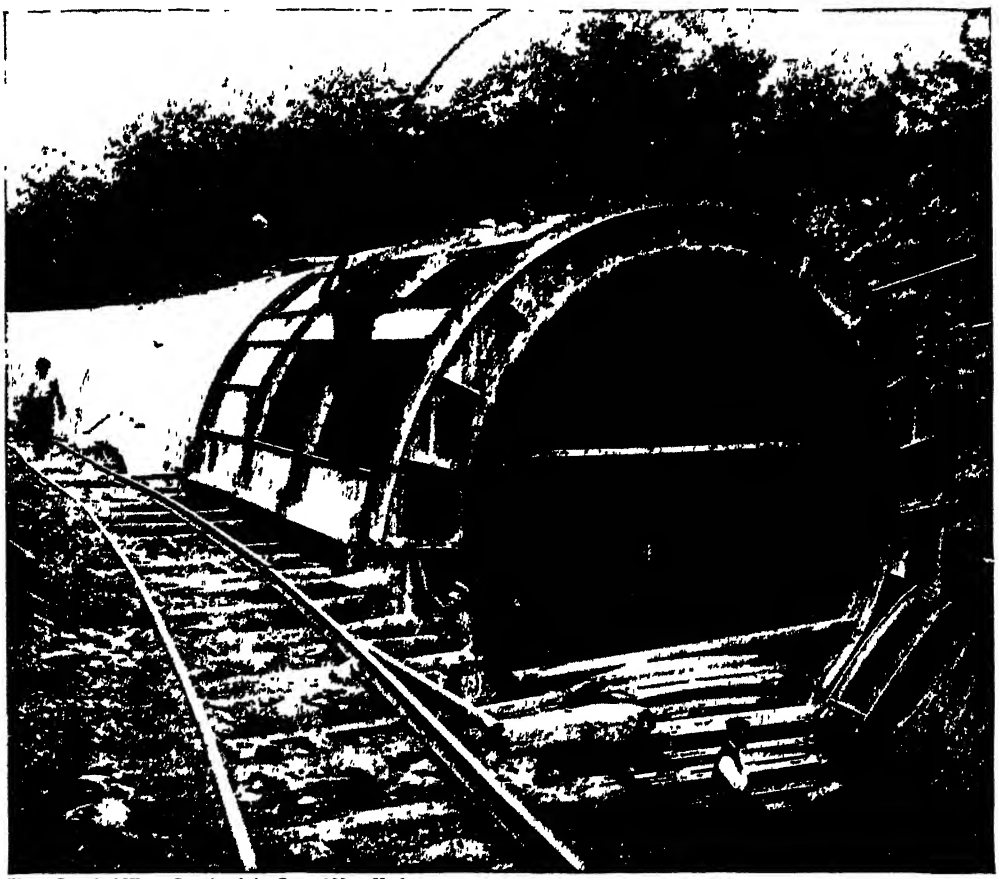
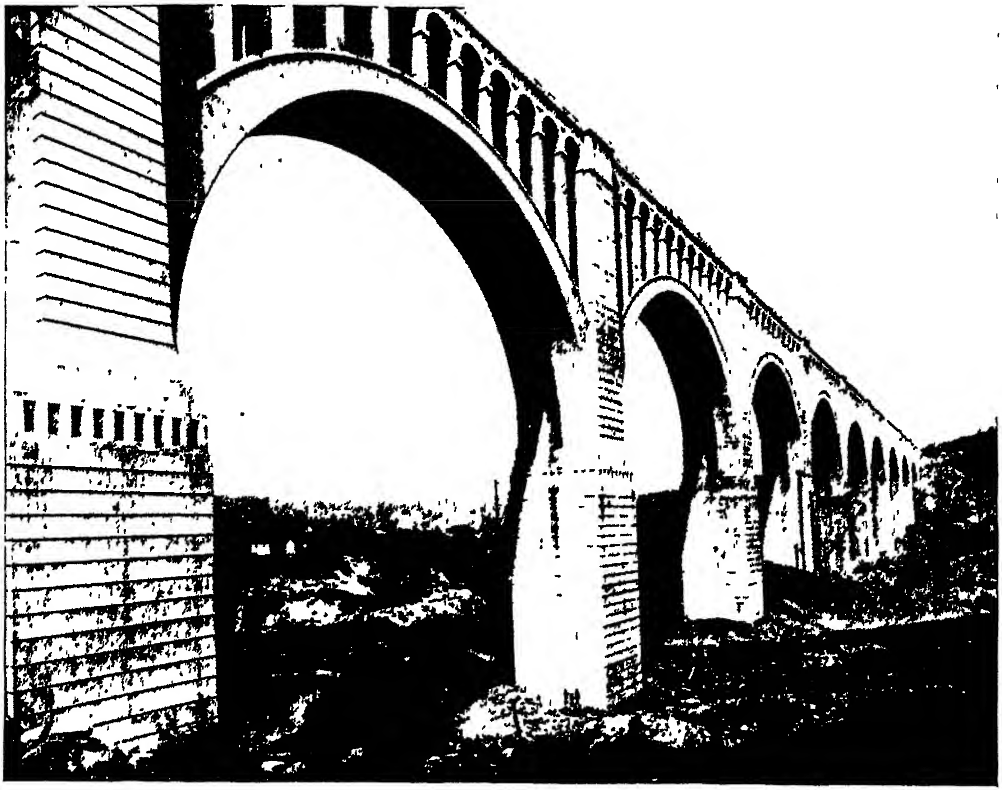


Photo Board of Water Supply of the City of New York

USE OF CONCRETE ON THE BIGGEST WATER TUBE IN THE WORLD

The Catskill Aqueduct, a great engineering triumph, has recently been completed. It is the longest water tunnel in the world, extending from the Ashokan dam at Esopus, N. Y., to Brooklyn and is



THE TUNKHANNOCK VIADUCT ON THE DELAWARE, LACKAWANNA & WESTERN RAILROAD

This is the largest reinforced concrete bridge ever built, being half a mile long and 240 feet high. It contains 4,509,000 cubic feet of concrete and 2,228,000 pounds of steel. The bridge has ten arches and the foundations go down 60 feet to reach solid rock.

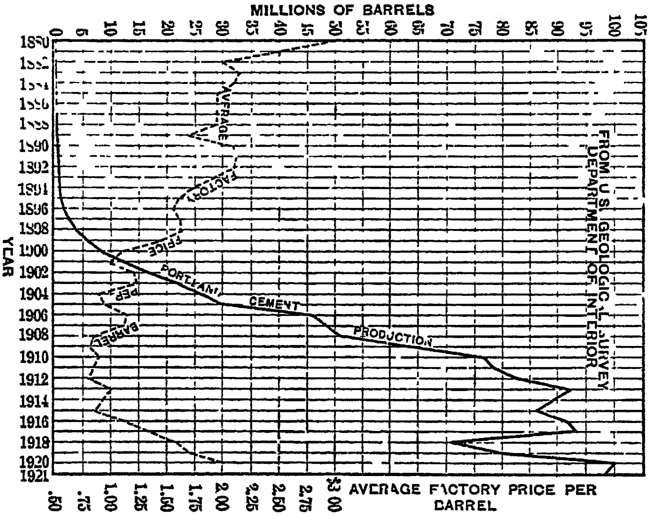
capable of supplying the City of New York with 500,000,000 gallons of water daily. In places this tube is 1100 feet underground and is subjected to a pressure of 90,000 pounds per square foot. This well illustrates the fact that reinforced concrete is strong and can be made almost perfectly waterproof. The aqueduct has been characterized as an engineering feat second only to the Panama Canal, where practically all of the construction was also of reinforced concrete. The Catskill aqueduct is treated at length and with further illustrations in the chapter entitled A City's Water Supply.

Courtesy of Alpha Cement Co

DELAWARE, LACKAWANNA & WESTERN RAILROAD BRIDGE JUST BELOW THE DELAWARE WATER GAP

Over 75,000 barrels of Portland cement were used in its construction.

In 1880 forty-two thousand barrels of Portland cement were produced in the United States at an average price of $3 each. The accompanying diagram shows graphically how this output increased through the years that followed to over one hundred million barrels in 1920, with the varying corresponding years' prices. The production in 1921 was 98,293,000 barrels.



A development in the use of concrete is the concrete block. Where blocks are used the expensive forms used for monolithic walls are eliminated. Blocks can be made on a small scale with the materials pressed into the forms by hand but when their manufacture is conducted on a large scale all the ingredients are proportioned by special weighing and measuring devices, mixed by machinery and pressed into the molds by hydraulic presses. The blocks generally have vertical openings to reduce the weight.

The cost of handling materials and blocks is also lessened by the use of conveyors and industrial railways. The strength of concrete blocks depends not only upon the materials used but also upon the care used in curing or hardening them after they have been removed from the molds. The best method of hardening concrete products is in a steam room. The steam is admitted through a perforated pipe immersed in a trough of water so that steam under pressure cannot come in contact with the fresh concrete.

Within the last few years there has taken place a considerable change in concrete block architecture. Various kinds of facing mixtures are now being used, and give, under proper treatment, a surface finish resembling granite or a number of other stone textures that makes a striking appeal to builders. The day of the old imitation stone face attempted by the use

Morgan Photo Service

CONCRETE IN HOME BUILDING

Concrete is much used in the construction and trim of charming bungalows like this one.

Courtesy Portland Cement Association

COLONIAL FARMHOUSE BUILT OF REINFORCED CONCRETE

Walls, floors, roof, stairs are of concrete Even the shingles, moldings and cornices are of concrete monolithic with the structure as a whole

of a fantastic facing plate in the block machine is passing. Certainly, block construction formed of units that presented a monotony which this practice displayed was far from pleasing. Portable houses or garages of concrete slabs, all ready to be set up, can be bought in a variety of not unpleasing elevations.

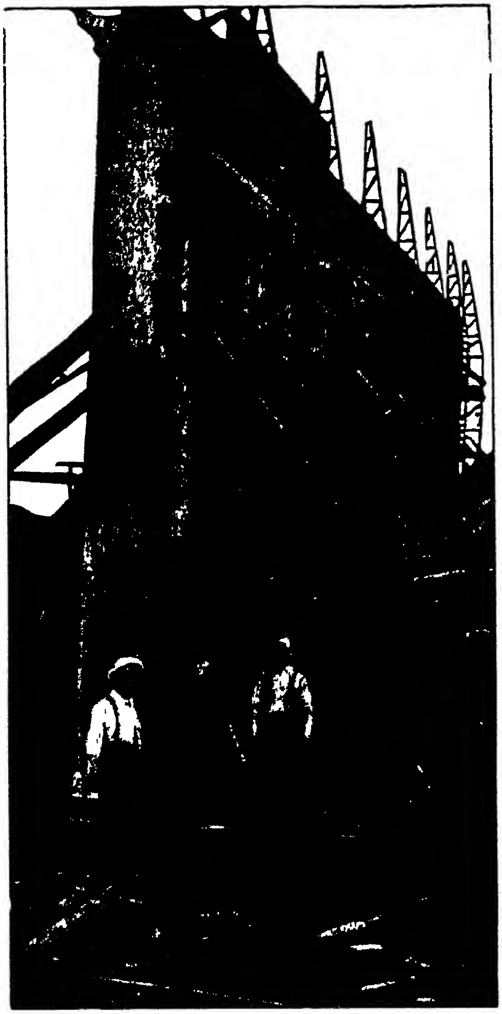
Economy is a consideration in favor of concrete as a material for house construction. While lumber and labor have advanced considerably, the materials used in concrete have increased only a trifle in cost. Cost is influenced, of course, by size, design, local conditions, etc.

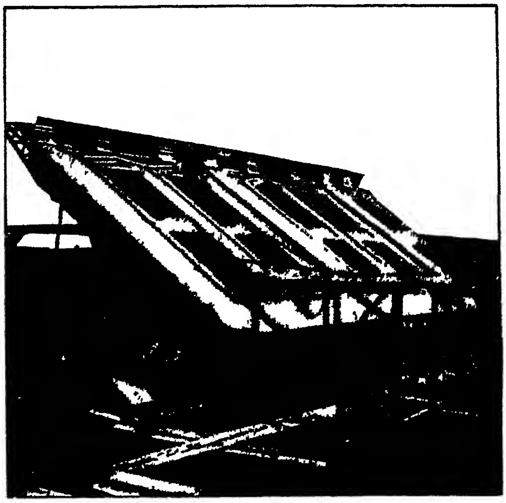
Rough cast concrete blocks form very desirable building units where it is intended finally to finish the exterior of a structure by applying a coat of stucco. Block buildings of this character may be erected at a cost which does not exceed a frame structure by more than 5 or 6 per cent, and a concrete block house is probably the lowest cost type of permanent fireproof building possible to construct.

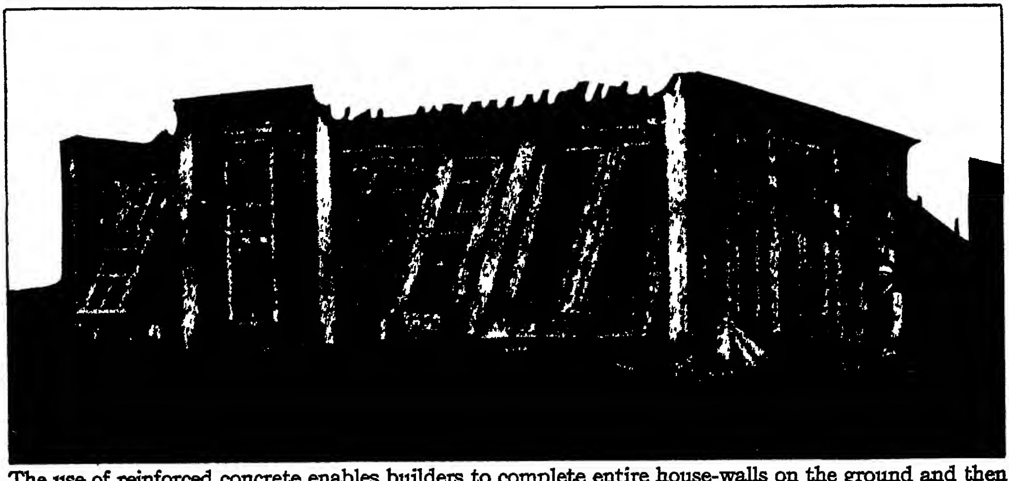
While the Americans have been developing the science of concrete work, the architects of southern Germany have made splendid progress in the artistic employment of the new material. Severe and simple in treatment, but exquisite in proportion their large buildings and small houses have both beauty and character Erected in a city or town, their white façades, in which the windows are finely placed, ennoble and dignify a street; and when one of these white houses is set in the green countryside, it mingles with the landscape in a picturesque way which delights the eye.

In America we are making churches and houses in sections. A wooden platform is laid on the ground, and machinery is placed beneath it, by means of which it can be raised. All door-frames, window-frames and other openings are set in their proper positions on the platform, and the reinforcement of steel rods is arranged horizontally and vertically. Then the concrete is poured in. In this manner a wall 200 feet long and three stories high can be cast in a single day. It is allowed to set for forty-eight hours, and then a small engine puts in motion the machinery beneath the platform, and the huge wall rises from the inside, slowly and quietly, to its permanent upright position. When all the walls are in place, the corners from which steel rods project and interlock are "poured," and floors and roof of concrete are cast in the ordinary way. The wooden platform and its machinery can be used over and over again.

A BUILDING MOLDED ON THE GROUND

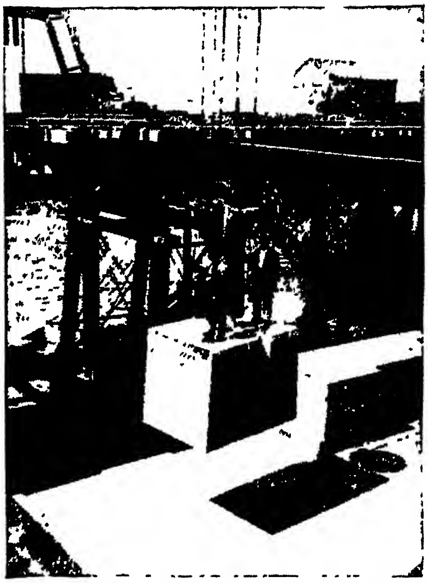






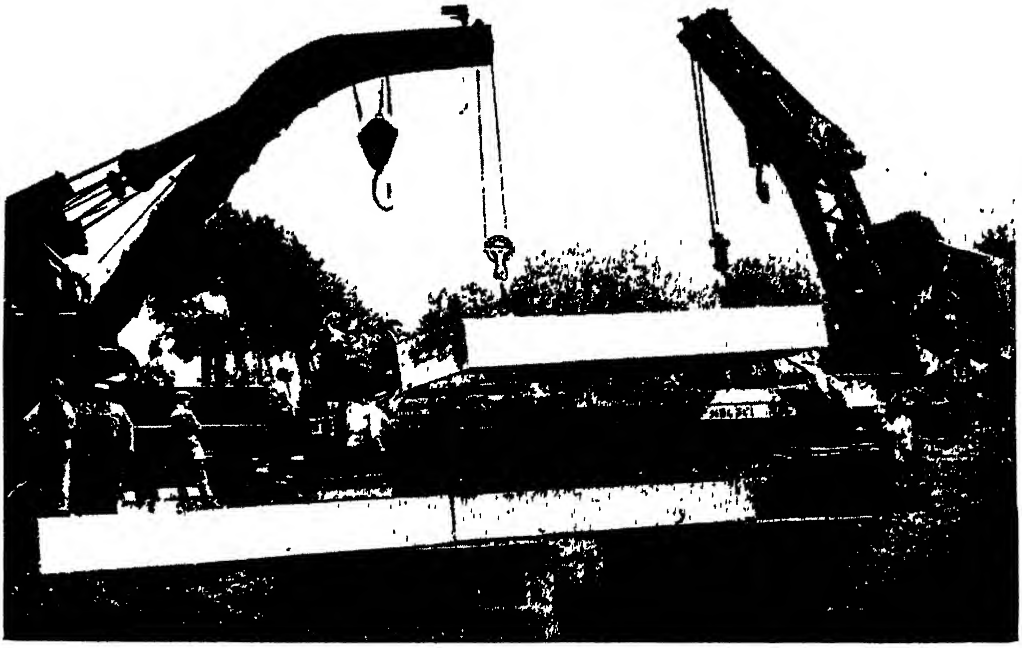
The use of reinforced concrete enables builders to complete entire house-walls on the ground and then raise them into position In these pictures we see a military mess-hall in course of construction, the bottom picture showing the front seventy-six-foot wall being raised to its vertical position

Concrete houses are stronger and more completely proof against damp and fire than other forms of construction. They cost less to build and less to maintain, owing to the extraordinary durability of the new material It can be made in various colors, and molded into harmonious lines and exquisite forms From the point of view of health, no building material can be compared with it. Hospitals and schools and large buildings should be constructed entirely with it Especially is it necessary to do away with wooden floors and wooden stairs and all kinds of boarding This is easily done in a modern concrete building, where the floor and wall surfaces can be designed in softly beautiful colors Concrete is vermin-proof, no rats or mice or insects can burrow into it Moreover, the fungus growth which spreads in the course of time in old buildings cannot form on the new material, and there are no lodging-places for the microbes of disease By means of a hose, a building of reinforced concrete can be cleaned inside and out with ease and rapidity.



PLACING 40-TON CONCRETE BLOCKS IN BREAKWATER CONSTRUCTION

Cheap and beautiful, sanitary and everlasting, modern concrete is surely destined to revolutionize the habitations of man throughout the world.



A BRIDGE OF CONCRETE BLOCKS THAT WAS ERECTED IN A DAY

THEODORA OF BYZANTIUM

THE DANCING-GIRL WHO BECAME AN EMPRESS

By VAL PRINSEP, R.A

WOMAN'S PLACE IN THE SUN

The National Folly of Repressing the Intelligence and Individuality of the Mothers of the Race

FREEDOM OF WOMEN IN THE EARLY WORLD

IN many ways, life at Athens in the days of Pericles was the summit of human achievement, never since attained. No doubt we have improved in certain directions upon it, but what we have gained does not make up for what we have lost. The Greek mind at its best remains the ideal, and the civilization created by the Athenians shows, in a small but perfect way, some of the harmonious lines on which, we hope, our own disordered civilization may in time develop.

The portentous thing about this miraculous period in Athenian history is that the work was done practically without any aid whatever from women. More than this, it was carried out by men who deprived woman of every social, political and public right, and imprisoned her in her home.

"Aspire only to those virtues that are peculiar to your sex, and think it your greatest praise not to be talked of one way or another," said Pericles, in his famous speech to the Athenian women. Women were only servants in the house of their fathers or husbands, and from youth to old age they were regarded as minors. They were not allowed to mingle in the society of men; they were not educated to take part in intellectual conversation; and their lives were chiefly spent indoors, tending to the children, spinning and baking, and doing domestic work. The Athenian woman, save in her capacity as the mother of children, was despised by some of the best minds of Greece. "A slave," said Aristotle, "is entirely deprived of the faculty of deliberation; children possess it, but it is incomplete and imperfect; and the woman has it, but only in a feeble and inefficacious way."

The freemen of the city which thus contemned its women were scarcely more than 31,000 in number — and yet they broke the power of Persia at Marathon and Salamis; they created many of the chief arts, established free institutions and practically created European civilization. "Nothing lives and moves in the modern world," said Sir Henry Maine, "which is not Greek in origin." How are we to reconcile the splendidly effectual work of the Athenians with the deplorable position in which their women were kept? Does it not look as though men have no need whatever of women, except as mothers of their children?

And we have a more recent example than ancient Athens of the apparent uselessness of the woman in civilized society. Ever since Marathon the European races have felt themselves to be generally superior to the peoples of Asia. Here and there the Asiatic has occasionally beaten us back by force of arms, but, on the whole, we have seemed to excel him in both the arts of war and the arts of civilization. A few years ago, however, Japan suddenly showed herself to be as well organized and as powerful as a great European power. Far more suddenly than ancient Greece, she acquired the culture of the advanced nations around her, transformed it into something original, rearranged her national life, and sprang forth full-armed, enlightened, progressive and expansive.

Yet at the very time that this wonderful development was taking place, the Japanese woman remained in a position remarkably similar to that occupied by the Athenian woman.

Trained from her cradle to habits of docile subjection, she took no part whatever in the magnificent work of revolution done by the Japanese man Sweet, pliant, colorless, without any ideas or will-power of her own, the Japanese woman passes from the rule of her father to that of her husband and her husband's parents She is a silent, laborious little housekeeper, from whom nothing more is asked than that she should bear her husband children — sons, preferably — and prepare his meals and look after his house and his clothes. She has practically no rights If her husband ill treats her, she must still meet him with a smiling face, and he is able to divorce her on various slight pretexts.

How war has been the great enemy of woman in social life

It is very doubtful if the change from barbarism to civilization improved the social position of woman. We have already pointed out that it benefited her in other ways, by helping to make the marriage bond more stable, by mitigating the incessant drudgery which shortened her life and human life generally, and by leaving her free to pursue the gentler and more domestic arts. On the other hand, the organization of civilized society was mainly effected by war. The development of agriculture, in which woman originally played so important a part, resulted in certain races of mankind taking to a permanently settled way of life. The idea of landed property, whether held by single families or in commonalty by the clan, introduced into the agricultural state a constant source of strife. The individual passion of greed was born, and the sword was fiercely used by wealthy landowners against their weaker neighbors. Certainly one of the earliest civilizations of which we have any record — that of Egypt — was founded by slaughter and usurpation. First we meet tribes of farmers continually at war with each other; and when they are at last united into a nation under a single ruler by a series of conquests carried out by the clans of the Thebaid, we find that all the machinery of despotism has been created.

The tradition of equality of the sexes upheld in the earliest ages

It is at this stage that the degradation of woman begins. Happily, in the very earliest civilizations, woman managed to retain something of her position as helpmate to man. In Egypt, and still more in Babylonia, the status of women was higher than in many later civilizations. Traditions of the economic equality of the sexes were too recent to lose their efficacy.

Early Babylonia is quite extraordinary for the freedom allowed to its women Their partnership was much valued by the men they married, and a distinct industrial position was maintained by spinsters. They formed themselves into large co-operative societies, under religious sanctions, with vows of chastity. Unlike Christian nuns, they were free mistresses of their time and their labor. They lived where they would, and worked at what they liked, protected by their society as long as they kept their vows and paid their dues. Among the Hittites of Asia Minor, women had a similar high position and economic liberty, as they did also down to Greek times in backward Lydia. Agriculture and industry represent brains and perseverance; and wherever these two qualities had been long enough dominant at the dawn of civilization to prevail against strength and animal courage, woman succeeded in preserving something of her social and legal freedom, even though man controlled the political system.

Man, undomesticated by war, drives woman into seclusion of the home

But as civilizations increased in number and in power, the sword became more powerful than the plow. The great kings took to keeping standing armies, first to defend their subjects, and then to extend their dominions. Small, peaceful, farming races were destroyed, and the warrior, bred to violence and rapine, became the master of society. Woman then began to fall, as she fell in Christendom during the fierce, brutal, feudal era. When civilized warfare became general, the work woman had done in domesticating man was undone.

Agriculture produced an abundant and regular supply of food. This led, on the one hand, to overpopulation and expansion into new territories, often, no doubt, by main force And, on the other hand, the comparative luxury of the farming nations excited the cupidity of neighboring tribes of hardy, semi-nomadic shepherds and cattle and horse breeders. Man again became a hunter — a hunter of men — and the civilizations woman had founded by the arts of peace were now maintained by the arts of war.

Driven by the sword from the fields she had taught men to till, woman fled to the shelter of the house There henceforth she remained, first under the loving protection and then under the dominion, of the men of her family. Her position seems to have been made worse by the fact that a series of successful invasions of pastoral tribes everywhere re-introduced into the fabric of civilization the older patriarchal form of family government. This type of family was developed almost wholly by men under the conditions of pastoral life, where the economic value of women was slighter than in the higher stage of agriculture.

Man domesticated, bred and guarded all the milk-giving and flesh-giving animals, and found children almost as much help to him as women; so, in this state of culture he tended to confine his wife, or wives, to the task of keeping house for him and bearing him useful children.

The Jews are a remarkable example of a pastoral and patriarchal race which won, wholly by means of the sword, a civilization which it did not understand. It invaded a fertile, agricultural land, and took over the novel arts of agriculture, but retained its old patriarchal customs When the Jew settled down to tilling the soil, a great deal of the work fell on the woman, but she was allowed none of the freedom of the women of the early, exclusively agricultural states. The misfortune that befell the Jewish woman, through the survival of pastoral laws in a more advanced society, affected for the worse the lot of the European woman thousands of years afterwards.

China and India seem also to be instances of the survival of the hard, tyrannical, patriarchal form of government in a civilized society developed from a later agricultural settlement. Compared with the Egyptians and Babylonians, the Chinese and Hindus are late arrivals in the world of civilization; and, like some other laggard races, they made their women pay the price for their backwardness. "Day and night must women be held by their protectors in a state of dependence," runs the law of Manu, the earliest and rather mythical legislator of the Hindus "A bride should only be a shadow and an echo in her husband's house," says an old classic Chinese writer In an ancient Chinese book which still serves as an authority on education, it is said: "On reaching the age of ten years, daughters must never be allowed to go out of the house. They must be taught to be amiable, to speak gracefully, to spin flax, to work silk, and to sew. At the age of twenty, they must be married" The life of a Chinese girl of the wealthier class is still directed by this ruling. Early in childhood she is secluded in the house, her mind and her imagination are starved, and her will power is broken She is an extraordinary example of the great power of education. All her individuality is taken from her, and she is transformed into the most passive human creature in the world.

The broken souls of the women of China, the world's most passive creatures

"Heaven," say the Chinese, "has given woman modesty and innocence for the good of the family and the welfare of the children; and to man has been given the strength of body and soul to govern her."

Thus the woman in the most ancient of existing civilizations is allowed no personal and individual life. She exists wholly for the sake of her family and her children. Only in her old age does she win a little honor, if she is the mother of men. The Chinese say: "The mother happiest in regard to her daughters is she who has had only sons." The ingenuity with which the men of China have broken the souls of their women, and molded them into docile slaves, is almost satanic in its cleverness.

In spite of the fact that they have exercised over the mothers of their race a moral, intellectual and physical tyranny, extraordinary alike in its scope and its duration, the Chinese have for thousands of years survived all manner of revolutions and invasions, increased enormously in population, invented many arts and industries, and grown, on the whole, into a sober, peaceful, hard-working nation.

How the emancipated women of Greece lost their advantage

With the exception of the earliest agricultural states, hardly any ancient civilized race in the days of its power promoted the social and political equality of the sexes. The peoples of Europe scarcely treated their women better than the peoples of Asia. As is well known, the Hindus form a branch of the European family; and when they invaded India they had a barbaric culture similar to that of the primitive Greeks and Romans, Teutons and Celts. So, originally, the position of the Hindu woman was fairly high; but when her nation became civilized she gradually sank almost as low as the Chinese woman and at the present day she remains on the same humble level as her sisters in China.

The Greek woman fell in the same way when her race invaded Greece, except among a few late-coming warlike tribes, like the Spartans, who held for military purposes to many of the traditions of their old barbaric way of life. What the Greeks were like in their semi-civilized days we know fairly well from the works of Homer. The Greek woman then had not lost her freedom. In the days of Pericles, however, she was only a household slave, suffering, if we may believe Euripides, from neurotic disorders, and chafing against the bars of her prison house. When she managed to emancipate herself, in the days when the Greek spirit was broken and weakened, she did not set a very good example. Neurotic, capricious and greedy for excitement, she occasionally worked her way by intrigue to positions of power and glory; and there, like Cleopatra — who was a Greek and not an Egyptian — she ruined the nation she undertook to govern.

The dignity attained by the strong and wise action of the mothers of Rome

The emancipated women of Greece were well known in Rome. They became the stock figures of Roman comedy; and the hatred, anger and contempt which they excited told heavily against the Roman woman The Romans arrived at civilization by the ordinary way of agriculture. They were a race of warlike farmers, fighting among themselves, fighting with their neighbors and fighting with the world, and always fighting for land. What they won by means of the sword they retained by means of the plow. So long as they remained militant agriculturists, their women preserved a certain independence of spirit.

The man-made laws were against the woman, subjecting her entirely to the father of the family; but in the agricultural days economic conditions favored her, and, like most farmers' wives of a capable sort, she had as much strength of character as her husband. She was like many a peasant woman of the present day — a strong, managing, industrious body, too busy to attend to matters of state, but as eager and as active as her husband in looking after the farm. Yet her social life was always much freer than that of the Athenian woman, and at times she was a wholesome force in the state. Not being locked all her life within the four walls of a house, she developed a sense of national duty.

The natural result of this was that in times of grave peril to the community she often displayed a remarkable patriotism. Under the Emperor Claudius, some legal rights were allowed her, and in the age of Justinian and Theodora her position in the empire became one of great personal and proprietary independence.

It is doubtful if the Roman woman was much indebted to the Christian Church for this victory over the traditions of pagan Rome. She appears to have won it partly through her own force of character, but mainly through the growth of finer feelings and larger ideas in Roman civilization itself.

Early Christianity was less favorable to women than Roman law had been

We are apt to overlook the fact that among the Romans there was a natural progress in humanity and justice which, though merged at last in the general teaching of Christianity, was European in origin This fact is clearly brought out by the remarkable conflict between late Roman law and the canon law of the Christian Church in regard to the personal rights of women

Under canon law, the wife was again subjected to the will of the husband. Here we arrive at the point at which the traditions of the patriarchal régime, preserved by the Jews, began to affect for the worse the position of the European woman. There is nothing in the teaching of Christ which makes in any way for the subjection of woman Quite the contrary. A divine foolishness, a strength in weakness, before which the power and the cunning of the world fade and are discomfited: such are the qualities of the Christian spirit as expressed in the actual words and the actual example of Jesus. And these qualities are surely found more often in women than in men. The Christianity of Christ and the progress of Roman thought might have concurred in producing a social and legal equality of the sexes, but a change came with the Christianity of Paul.

The bad effect of St. Paul's Jewish attitude towards women

Paul began as a Pharisee. He belonged to the straightest sect of the Jews, and held to the traditions of the patriarchal era, preserved in the Mosaic institutions. We have already seen that under the patriarchal customs the Jewish woman had little or no personal rights. She was subjected to her husband, so that she could not make a vow without his consent. A man could even sell his daughter into bondage, and, in short, the women of Isreal occupied a position similar to that into which other Oriental women have fallen. "The badness of men," says the writer in Ecclesiasticus, "is better than the goodness of a woman."

Such was the force of the Jewish patriarchal traditions that Maimonides, the great Jew of the Middle Ages, who was in many ways the forerunner of the modern movement, held that woman should be kept uneducated and confined to the care of the house. So it is not surprising to find that St Paul took a rather Jewish and Oriental view of her position. And perhaps in framing rules for the Gentiles he was influenced by the ancient customs of the Athenians.

However this may be, St. Paul undoubtedly threw the whole weight of his authority against woman; and his prejudices were to a considerable extent embodied in the canon law of the Christian Church. In modern times in England, Milton became the impassioned advocate of the Pauline view of the subjection of woman; and it is probable that the ideas on the matter contained in "Paradise Lost," supported as they are by many texts in the Bible, have had some directing power over the course of English, Scottish and American thought.

The curious decline of woman's power in the freedom-loving north

We have now arrived at a very interesting problem. As an actual fact, the European woman — or rather the woman of the northern European races who built themselves into nations on the ruins of the Roman Empire — has for centuries occupied a high position in society. Yet everything, apparently, has been against her. Most of the traditions of the older civilization were opposed to her; the canon law assigned to her a very humble place in society, and many of the Fathers of the Church, who were the spiritual legislators of Christendom, regarded the daughters of Eve as a malign influence in human life. Moreover, the European woman of the new order belonged to a horde of fierce, ignorant and barbaric fighting men, who overturned the culture of Greece and Rome, and threw the greater part of the ancient world into a welter of dark, ferocious anarchy, delaying the advance of civilization for a thousand years.

One new fine thing, however, the northern barbarians introduced into the civilized world which they swiftly ruined and slowly built up again They brought with them a higher ideal of woman than the Roman, the Jew or the ancient Athenian possessed Rising directly from a semi-agricultural state of society, in which the wife was more the helpmate than the servant of the husband, they gave the mothers of their race a nobler place in the common life than even the Roman matron won in the days when the Romans were still farmers.

The Anglo-Saxon woman, in particular, arrived at a very happy position, perhaps because the laws of her people were evolved directly from Teutonic custom without any important influence from the canon law or Roman law. The laws of Ine gave a wife a third of her husband's property; and the laws of Edmund allowed this to be increased to one-half, if a settlement was made before the marriage In France vestiges of a primitive mother-right remained, before Charlemagne revised the old Frankish common law from a Roman point of view For instance, if a man died without children, his mother and father equally shared his property, if they were dead, then his maternal aunt inherited before his paternal aunt

Unfortunately for the Englishwoman, the laws of the Scandinavians were entirely different from the laws of the Teutons in regard to the rights of women. Perhaps the art of agriculture was much less practiced in the more northerly and colder country, and the economic value of women diminished. The maids and wives of the Scandinavians were under perpetual guardianship. Up to the end of the seventeenth century, under Christian V, the guardian of a woman obtained the benefit and administration of her goods during her life, if she took upon herself to marry without his consent.

WOMEN OF SIENA REBUILDING ITS WALLS

Though woman is regarded as the weaker vessel, she has often played an heroic part in defending her country, as the women of Siena did by helping to rebuild and defend the breaches in the walls of their city when it was attacked in 1553

What that meant in practice can easily be imagined We know it from English history, for our ancestors had some experience of the rigor of Scandinavian law First came the Danes, sweeping Great Britain and Ireland; and then, a few days after the last Norwegian raid, another branch of the Norway clans — the Normans — conquered England and Wales, invaded Ireland and made Norman law the law of the land.

Swift and profound was then the degradation of the Anglo-Saxon woman The person and property of a wife became entirely at her husband's disposal. A woman could not even accuse a man of murder, except only in the case where it was her own husband who had been killed. It was the day of

> "The good old rule, the simple plan,
> That they should take who had the power
> And they should keep who can."

And woman, being unable to keep anything in her gentle hands, lost everything. In the silence of a moonlight night, the harshest and the ugliest scene often puts on a wild, romantic beauty, factory chimneys loom out of the darkness like enchanted minarets, and unlovely stacks of cheap bricks and mortar show dimly forth like mysterious castles. So, in the silence and moonlight of history, the mean, brutal savage age of feudalism takes on the soft, quiet, glimmering colors of romance.

The false glamour of chivalry

But, as a matter of fact, most of this romance is false; and where it is not false it is often unseemly. Open rapine and underhanded cunning, barbaric violence, mitigated by fits of superstition, formed the prose reality of the age of chivalry; and nearly all the poetry of the age celebrated adulterous love. Scarcely a single love lyric of the troubadours and other minstrel knights was addressed to an innocent, unmarried girl. Not until the freemen of the middle classes in the towns of the Middle Ages became strong and wealthy and independent enough to create a culture of their own, did medieval literature acquire a purer tone, and women win again an honorable position in society.

It is true that, when strict military service was not required from the feudal landowner, the lot of the noblewoman was somewhat improved. She was then often allowed, in the absence of a male heir, to succeed to a fief. But even the great heiress was not free in the one matter of high concern to her. She often had to marry the man chosen by her overlord; she was a piece of valuable property, a prize of great price in the feudal game of slaughter, intrigue and treachery, and when Europe became more settled in the fourteenth century, female heirship was largely abolished. For instance, the Golden Bull of 1356 declared that all the fiefs held directly of the empire would only be transmissible to male heirs.

"One should not teach any woman to read or write," says a French writer of the twelfth century, "if it is not especially to make her a nun. For it is extremely unbecoming in a woman to read or write."

Competition in trade by city women

Woman, however, had one weapon left, and when she belonged to the middle classes of the trading towns she used it. There were things she could make and sell as well as a man could. In many country districts the communal type of family obtained, and there the woman of the peasant class merged her activities in the activities of the group. In cities, however, there was scope for individual enterprise; and here, in the thirteenth century, we find woman entering single-handed into commerce. For women merchants were then given the right to bring actions at law without their husbands' consent — a thing a French woman now cannot do. In England in the fifteenth century there was a successful agitation for the protection of the trade interests of woman. These events, nevertheless, are like many other single instances of feminine rights and powers in the history of medieval Europe. Collected together, they give an impression of progress, which is not confirmed when the very widely scattered and almost accidental facts are studied in their natural order of date and place.

The position of woman improves as civilization and free institutions develop

Yet the great European nations of the Middle Ages never lost entirely their high, traditional idea of woman After all, they came from the race which definitely instituted monogamy. In the darkest days of the medieval era, a Catherine of Siena, a Joan of Arc, showed, by the extraordinary power she exercised over the soldiery and the politicians of Europe, that the majority of the common people still recognized and responded to the feeling embodied in the figures of the Mother and Child which they placed in their churches. This deep and ancient undercurrent of emotion found clearer expression when the middle classes began to win their way to political power As civilization and free institutions developed, the woman of the more advanced nations recovered something of the high status possessed by the Roman matron under the later emperors.

In all kinds of ways she regained her economic value; the first daily English newspaper, for instance, was established by a woman. A considerable part of the textile trade was a domestic industry carried on by women in their own homes, and the housewife made most of the things which her modern descendants obtain from factories. In Elizabethan England women, as we know, were allowed considerable personal freedom; and in the troubled period of the seventeenth century they gave many examples of a strength of character comparable only with that of the Roman woman of antiquity.

At the Stuart restoration, however, the English woman's lot changed for the worse. Her brief period of spiritual emancipation had not lasted long enough for the old harsh feudal laws to be modified in her favor; and the Puritans left behind them, especially in the works of Milton, much of the old Jewish and Oriental view of the subjection of woman.

In America, as is natural in a frontier country — due to the free, democratic spirit, and to the high economic value of woman's services — she has always held a higher place than in any Old World civilization. At the present day, the woman of the Anglo-Saxon races is starting throughout the world a movement of tremendous importance She is, more by example than direct teaching, sowing the seeds of revolt over all the earth, and arousing her sisters from their slavery, just as the man of the Anglo-Saxon races is creating in the ancient despotisms of the Orient a series of revolutions in favor of free institutions of government. If both these movements succeed, then the form of family life in the East will be profoundly modified The Chinese woman will no longer resemble the Athenian woman of the age of Pericles; the Turkish woman, too, will escape from her harem; and the Japanese woman, who is already changing, will have a soul of her own. These tendencies have been hastened as a result of the Great War

If the full exercise of natural intelligence by the mothers of a race has any effect on their children by reason of the better training they are able to give them, if a marvelous increase in the force of character and play of mind of one-half of a nation adds to that nation's moral and intellectual power, then it seems likely that Pericles of Athens, Confucius of China, Manu of India, and the sages of Islam and Israel were gravely at fault in making the practical enslavement of woman the foundation of a civilization.

Athens perished less than a hundred years after the death of Pericles; India, once the center of the thought of the world, has lived on, in a sort of senile immortality, thinking over and over the thoughts she struck out in the days when her women had a part in her national life; the Jews have shut themselves up in the traditions of the patriarchal age, and compelled their finest spirits, like Spinoza, to leave them in order to speak to civilized humanity; the Chinese mind has stagnated since the days of Confucius; and Islam, once the spear-head of civilization, has fallen back almost to barbarism. This is perhaps a sufficient answer to the question we started at the beginning of this chapter.

ASTRONOMERS

DOMINIQUE FRANÇOIS ARAGO
A Man who Faced Pirates to Extend Knowledge

ARAGO, a great French astronomer and physicist, was born on February 26, 1786, at Estagel, a little town north of the eastern end of the Pyrenees near Perpignan The boy was entered for a military career, but the ability he showed in mathematics at the Polytechnic School, which he entered at 17, brought him an appointment in 1804 as secretary of the Paris Observatory, and he was sent by the government in 1806, with Biot, to carry out geodetic surveys in the Balearic Islands Their mission resulted in unexpected hardships and misadventures. Mistaken by the revolutionary Majorcans for a spy, Arago narrowly escaped in the disguise of a peasant, and, having reached Algiers, embarked for Marseilles. But his return was almost as laborious as that of Ulysses. A Spanish corsair captured the vessel in which he sailed; a period of imprisonment with merciless ill-treatment followed; and when set at liberty, and once more embarked for home, Arago was driven by tempest on to the African shore, three days' journey from Algiers. It was not until 1809 that he reached his native shore. As a reward for his sufferings in the cause of science, he was elected a member of the Academy of Sciences, though only 23 years old, and was appointed professor of analytical geometry and geodesy at the Polytechnic.

Although no ordinary discoverer, Arago was greatest as an interpreter of science. His lectures on astronony, etc., gave a life and a flavor to knowledge, which secured for it quite a new public, and initiated the era of popular interest in scientific matters. On the other hand, his studies in electromagnetism were of great value, and he was the first to show the relation between the aurora and terrestrial

DOMINIQUE FRANÇOIS ARAGO

magnetism. His investigation of light confirmed the theory, now universally accepted, that light consists of vibrations or undulations in the ether; and his invention of the polariscope was the beginning of a great advance in the science of optics. Arago was appointed in 1830 perpetual secretary of the Academy, and director of the Observatory. He died on October 2, 1853.

ARCHELAUS
Who Denied that the Earth was Flat

EARLY Greek philosophy, before the days of Socrates, was almost exclusively a fantastic and materialistic cosmology. But Anaxagoras of Clazomenæ, who settled in Athens about 456 B.C., and died in exile in 428 B.C., made a great advance when he realized that matter alone could not be the ultimate reality of the universe, but that Mind must be concerned in the ordering of the world. Among his pupils none was more distinguished than Archelaus, who was the first to deny, from direct observation, the flatness of the earth, which had hitherto been taken for granted.

Archelaus had pondered upon the fact that the sun does not rise and set at the same moment in all latitudes, but that the day is longer in summer and shorter in winter in northern regions than it is towards the south. Rightly perceiving that this inequality in the hours of sunrise and sunset at different latitudes was incompatible with a flat or plate-like form for the earth, he proceeded to the erroneous conclusion that the earth is not spherical, but hollowed out like a cup, being high at the rim and depressed at the center. He could never have fallen into this mistake if he had known that the rising and setting of the sun are earlier in eastern than in western regions.

It is not worth while to enter into his other cosmological speculations, which were as wild and baseless as any which had preceded them; but it is worth noting that the demonstration, based on undeniable facts, that the earth could not possibly be flat, was not long in leading to a sounder hypothesis than any which Archelaus had been able to imagine. For there is no doubt that about this period the Pythagoreans began to entertain the true belief in the sphericity of our globe.

ARISTARCHUS
The Man who Found that the Earth Revolves

ARISTARCHUS of Samos, a Greek astronomer of the Alexandrian school who made his observations about 280–264 B.C., has the honor of having been the first to proclaim the orbital motion of the earth round the sun, thus forsaking a geocentric for the heliocentric view of the solar system. His predecessor, Heraclides, had discovered the rotation of the earth about its own axis, and had described also the heliocentric orbital movements of Mercury and Venus, but had failed to conceive of our globe as pursuing a progressive movement round the sun. Archimedes, a contemporary of Aristarchus, refers to his theory in the following terms:

"He supposed that the fixed stars and the sun are immovable, but that the earth is carried round the sun in a circle." Plutarch remarks that Aristarchus believed "that the heavens stand still and the earth moves in an oblique circle at the same time as it turns round its own axis." Seleukus, a Babylonian, who lived about 150 B.C., followed Aristarchus in the belief in the daily rotation of the earth, if not in its annual journey round the sun, but at that point the conception of the earth's orbital movement disappeared from the mind of man for seventeen hundred years. There is little doubt that in his own time, and by the immediately succeeding generations of astronomers, the bold conception by which Aristarchus anticipated Copernicus was received with general incredulity, if not with horror.

Little is known of Aristarchus, and his one short essay which has come down to us, "On the sizes and distances of the sun and moon," shows only his method of estimating the relative distances of the sun and moon from the angle formed by the two bodies at the observer's eye when the moon's phase reaches the first or third quarter, *i.e.*, when we see the moon is half full. The bodies then form a right-angled triangle, with the sun as the apex and the moon at the right angle, and the ratio of earth to moon and earth to sun is readily calculable. The impossibility of determining when the moon is exactly half illuminated makes the method impracticable, and, as there were in Aristarchus' time no accurate instruments for measuring angles, he came to the erroneous conclusion that the sun is about eighteen or twenty times as far from us as the moon.

JEAN SYLVAIN BAILLY
A Scientist in the French Revolution

BORN in Paris, on September 15, 1736, Bailly attempted in turn the arts of the painter, poet and dramatist, but was not long in finding his true vocation as an astronomer An account of his observations on the moon, presented to the Academy of Sciences, procured for him, in 1763, the rank of an academician. Thenceforward he specialized on the study of the satellites of the planet Jupiter, and was able in 1766 to publish a table of their motions, and later an investigation of their variations in brilliancy according to their position with regard to Jupiter and the position of Jupiter relatively to the sun and the earth. But literary work had still a great attraction for him, and he gradually forsook the observatory in order to compile a brilliant and comprehensive, but not always accurate, "History of Astronomy" (4 vols., 1775 to 1782)

With this work his career as an astronomer was interrupted Bailly was caught up in the storms of the French Revolution and, after enjoying enormous popularity in 1789 as first president of the National Assembly and mayor of Paris, he quickly declined from public favor. Having excited the hatred of the mob by his fearless condemnation of their false accusations against the queen on her trial, he was arrested in July, 1793, and executed on November 12 of the same year. His own "*Mémoires d'un témoin oculaire de la Révolution*" is an interesting study of those turbulent years. His astronomical labors, though very limited in amount, were of great value to science.

FRANCIS BAILY
A Great Reviser of Star Catalogues

IT is well known that during an eclipse of the sun the last view that we get of the disappearing edge of the sun's disc, and the first view that we get of its reappearance on the other side of the moon, are in the form of a crescentric series of separate points or beads of light. This phenomenon, erroneously supposed by some to be due to irregularities of the surface of the intervening moon, is known as "Baily's Beads," named after the English astronomer Francis Baily, who, though not the first to observe it, succeeded by his vivid descriptions in bringing it to the general attention of astronomers and thus powerfully stimulated observations of the *physical* aspects of solar eclipses Born at Newbury, on April 28, 1774, the son of a banker, Baily became a London stockbroker, and distinguished himself in that career. But his services to astronomy give him high rank among men of science. He was first attracted to the study of the heavens when writing an "Epitome of Universal History," published in 1813, having made, for the purposes of this book, a mathematical computation of the solar eclipse which was predicted by Thales, the early Greek philosopher. Baily was one of the founders of the Royal Astronomical Society, he was the first secretary of the society, and had much to do with framing its constitution. We have already alluded to his well-known observations during the annular eclipse of the sun on May 15, 1836. This, however, was not his most important astronomical work His skill in computation and extreme thoroughness in detail gave great value to his labors on star catalogues. He revised the catalogues of Ptolemy, Tycho Brahe, Halley, Hevelius, Flamsteed, Lacaille and Tobias Mayer, an undertaking which entailed an enormous amount of work Each star was calculated with such care that Baily detected errors which had escaped many previous students. He also wrote an admirable life of Flamsteed. He died in London on August 30, 1844.

SIR ROBERT BALL
Famous Student and Popularizer of Astronomy

SIR ROBERT STAWELL BALL was born in Dublin on July 1, 1840, son of the well-known naturalist Dr. Robert Ball He was educated at Trinity College, Dublin, and in 1865 was invited to take charge of Lord Rosse's giant reflector at Parsonstown, where many interesting observations were made and much valuable work done, especially in relation to nebulæ. While there he discovered four spiral nebulæ.

SIR ROBERT BALL LOOKING AT THE HEAVENS FROM THE OBSERVATORY AT CAMBRIDGE

In 1867 he was appointed to the chair of applied mathematics and mechanism in the Royal College of Science for Ireland, and in 1874 Andrews professor of astronomy at Dublin University, and director of Dunsink Observatory. From 1874 to 1892 he held the position of Astronomer Royal for Ireland. At Dunsink Professor Ball gave much time to the search for stellar parallax. He tested Nova Cygni for parallax, and determined that this new star must be at least twenty million millions of miles distant. He made a sweeping examination of the heavens for stars with measurable parallaxes, and new and careful determinations of those of 1618 Groombridge and of 61 Cygni.

In 1874 Ball began his career as public lecturer, in which rôle he obtained phenomenal success. He visited the United States in 1902, and addressed a number of audiences in Philadelphia and Boston. He was knighted in 1886, and in 1892 was appointed professor of astronomy and geometry at Cambridge. He died in 1913.

Sir Robert Ball was an extremely able and popular writer. Among his books may be mentioned: "The Story of the Heavens," "Starland," "In Starry Realms," "In the High Heavens," "The Story of the Sun," "The Cause of an Ice Age," "Great Astronomers," and a "Popular Guide to the Heavens."

Sir Robert Ball was a supporter of the nebular theory of the universe, but held that the nebula from which the solar system took its rise was a small one, comparable rather to the planetary nebulæ than to any of the great nebulæ, and that the formation of the solar system was due to the condensation of the primary nebula as it gave out its enormous initial heat. The sun and planets represent, under this theory, one large and several smaller centers of concentration of the primary nebula.

EDWARD EMERSON BARNARD
The Discoverer of Sixteen Comets

EDWARD EMERSON BARNARD was born at Nashville, Tennessee, December 16, 1857 As a boy he worked in a photograph gallery, and the knowledge he there obtained of the photographic art was of immense value to him in his astronomical work in later years. His earliest astronomical studies were undertaken alone. From 1883 to 1887 he was in charge of the Vanderbilt University Observatory at Nashville, whence, in September, 1887, he went to Mount Hamilton, California, where he spent eighteen years of fruitful labor as astronomer of the Lick Observatory of the University of California until October, 1895, when he became professor of practical astronomy in the University of Chicago and astronomer in the newly founded Yerkes Observatory, in which post he labored until his death on February 6, 1923.

Professor Barnard has credited to him the original discovery of sixteen comets. In 1883 he discovered that the small star BETA *Capricorni* was double. It is difficult to detect the double character of this star even with larger instruments than the one he was using, and the discovery was made possible for him only through the occultation of one of the pair of stars by the moon From 1879 to 1883 he made a long series of observations of the spots and markings on the planet Jupiter. These were afterwards printed in the Publications of the Astronomical Society of the Pacific. In 1882, while observing with his small telescope the great comet of that year, he found several companion comets to it, which were also independently discovered elsewhere. On December 6 of that year he observed the transit of Venus with his 5-inch telescope.

He continued his work on comets at the Lick Observatory, where, on August 1, 1889, he discovered several companions to Brooks's comet of that year, two of which were observed for several months. With the 12-inch and 36-inch telescopes he made many observations of the surface features of the planets Venus, Mars, Jupiter and Saturn. With the larger telescope he measured the diameters of all the planets and of the four brightest asteroids Ceres, Pallas, Juno and Vesta; as also the diameters of the four brighter moons of Jupiter and of Titan, the largest satellite of Saturn. While at the Lick Observatory he took up the work of photographing the sky with an old portrait lens formerly used in a photograph gallery in San Francisco. This became famous in his hands as the Willard lens of the Lick Observatory. With this instrument he made the first photographs that were ever

EDWARD EMERSON BARNARD

obtained of the cloud forms of the Milky Way. With it he also photographed Swift's comet of 1892 and showed in his photographs of Brooks's comet of 1893 what wonderful changes the tails of these bodies undergo, transformations so remarkable that they must be due in some way to disturbing forces in planetary space which break and distort a comet's tail. These photographs of the Milky Way and of comets were collected in a quarto volume printed by the Lick Observatory in 1913. While engaged in this work he was the first to discover a comet by photography.

On September 9, 1892, he discovered with the 36-inch telescope the fifth satellite of Jupiter, a very small body revolving around the great planet in less than twelve hours, at a distance of about 67,000 miles from its surface

At the Yerkes Observatory Professor Barnard continued his observations of the planets and their satellites and of comets With the Bruce telescope there he has photographed all the larger, and many of the fainter, comets that have appeared in recent years. Of Morehouse's comet of 1908 alone he secured more than three hundred and fifty photographs with the three lenses of the Bruce telescope. In 1905, through the courtesy of Professor George E. Hale, he spent the summer at Mount Wilson, California, in photographing the Milky Way with the Bruce telescope which had been transported there for the purpose. Some of the results are reproduced by the Carnegie Institution of Washington in a recent volume. He has proved from his photographs of the Milky Way that there are large dark bodies in space, perhaps non-luminous nebulæ, which are shown in dark relief against the bright galactic background.

With the large telescope of the Yerkes Observatory, Professor Barnard made a micrometrical triangulation of the individual stars of some of the great globular clusters of the sky, such as Messier 13, in the constellation Hercules; Messier 92, also in Hercules; and Messier 5, in Libra, and others. He also made observations of some of the remarkable variable stars of these clusters, especially of the star Bailey No 33, in Messier 5, which he observed carefully during a period of twenty-five years. His observations show that the period of its light variation, which is about twelve hours, is undergoing changes. The various new stars that have appeared in the past thirty years were specially studied by him.

The *Gegenschein*, a rather mysterious, feeble, hazy light, always opposite the sun and of whose origin we know little, was independently discovered by him. He observed it over a period of nearly forty years and also made regular observations of the aurora for the past twenty-five years, publishing during that period two lists of auroras

Such long and successful devotion to observational astronomy and the important discoveries resulting from it could not fail to secure for their author an international reputation, and the learned world conferred upon Professor Barnard many honors in recognition of his services to science. He was accorded the degrees of A M by the University of the Pacific (1889), of honorary Sc D by Vanderbilt University (1893), and of LL D. by Queen's University, Canada (1909), and was awarded the Lalande gold medal of the Paris Academy of Sciences (1892), the Arago gold medal (1893), the Janssen gold medal (1900), the gold medal of the Royal Astronomical Society (1897), the Janssen prize of the *Société Astronomique de France* (1906), and the Bruce gold medal of the Astronomical Society of the Pacific (1917). He was one of the associate editors of the *Astronomical Journal*, and held the office of vice-president of the American Association for the Advancement of Science (1898).

His high scientific attainments were united to rare personal gifts of mind and heart which are well described by one of his fellow workers and intimate friends: "He was marked by great simplicity of character, great modesty, perfect unselfishness and self-abnegation; a most kindly and genial spirit, most tender-hearted, making any distress of his friends his own distress, of such character as to make him genuinely loved by all who knew him"

JOHANN BAYER

A Man Who Made Over Fifty Star-Maps

JOHANN BAYER was born at Rain, in Bavaria, in the latter part of the sixteenth century, probably about 1572. Educated in the principles of the Lutheran Church, he became widely known as a bold and eloquent speaker, and received the nickname of *Os Protestantium* — the "Mouthpiece of Protestants." He also was a very zealous and useful astronomer, and received for his labors a title of nobility from the emperor.

It was in 1603 that Bayer brought out the work for which he is famous, entitled "*Uranometria*," or "Measurement of the Heavens" This contains descriptions of the constellations and fifty-one elaborate star-charts Its distinguishing characteristic is that here, for the first time, the stars in each constellation are separately designated by the letters of the Greek alphabet, and, when these have been exhausted, by the letters of the Latin alphabet. The method was at once found extremely convenient, and is in use at the present day The descriptions of the constellations are clear and the maps are fairly accurate. The latter retain the old figures of animals, heroes and other symbols by which the constellations have been denoted from antiquity It has been noticed that in many constellations the brightest star is denoted by the letter beta, or some later letter of the alphabet, instead of by alpha, and this was formerly thought to show that the stars had changed in relative brightness, but Argelander pointed out that Bayer began his lettering with the chief stars of a constellation in their order from north to south, and not in their precise order of brilliancy.

Bayer's catalogues are still of value, though his work preceded the invention of the telescope. He died in 1660.

FRIEDRICH WILHELM BESSEL
Father of Modern Observational Astronomy

FRIEDRICH WILHELM BESSEL, the German inaugurator of a new era in sidereal science, was born at Minden, in Westphalia, on July 22, 1784 Intended by his father for a commercial career, he entered a mercantile house in Bremen, but his youthful fondness for astronomy and mathematics soon led him to devote himself to science, in which he soon made his mark. By his twentieth year he had executed the reduction of Harriott's and Torporley's observations of the comet of 1607, later so celebrated by the great discovery of its periodical return by Halley. He communicated his calculations to Olbers who, quick to recognize his surprising aptitude for astronomy, recommended him as assistant to Schröter at Liliental.

Here Bessel directed his attention to a series of micrometric measures of the sixth satellite of Saturn with a view to the better determination of the mass of Saturn and its ring by means of the perturbations caused thereby in the satellite's motions This investigation forms the subject of several elaborate memoirs At Liliental, also, were made his observations of the comet of 1807, and a memoir published on its elements gained the Lalande prize of the Institute of Paris. In 1810 he moved to Königsberg to become director of the new observatory which the King of Prussia was building. In 1813 it was completed and observations begun, from which time to the conclusion of his life, in 1846, an uninterrupted series of the most valuable and important contributions to our knowledge of astronomy emanated from it Bessel was, of course, elected into almost every academy in Europe as an associate, and many distinctions were conferred upon him; among others, the order of the *Danneborg* by the King of Denmark, and that of the Red Eagle, with the title of *Geheimer Regierungs Rath*, and the order of Civil Merit by the King of Prussia.

No astronomer has ever gone deeper into the theory of instruments or exemplified that theory by more elaborate experiments His great work, the "*Fundamenta Astronomiæ*," affords "the first example of the complete and thorough reductions of a great series of observations, grounded, in the first instance, on a rigorous investigation from the observations themselves, of all the instrumental errors . . . resulting in a model catalogue such as the world had not before imagined." His "*Tabulæ Regiomontanæ*," published in 1830, was to facilitate the reduction of observations of the planets and fixed stars on a uniform system. Perhaps the greatest work of all was his determination of the parallax of the star 61 Cygni, the first measurement of a star's distance from the solar system, and a feat which opened new vistas in sidereal astronomy. The success of this undertaking is graphically described by Agnes Clerke in her "History of Astronomy" as "the first *published* instance of the

fathom-line, so industriously thrown into celestial space, having really and indubitably *touched bottom*." In geodetic measurements, the determination of standards of weight and length, and in a series of pendulum experiments, Bessel did important work In the first, he conducted, with General Bayer, the triangulation of eastern Prussia; in the last he deduced formulæ for the determination of the length of the pendulum The fixation of the Prussian standard of length, ordered by law in 1816, after remaining nineteen years in abeyance, was committed to Bessel in 1835, and he completed the task in two years

"It is not too much to say that Bessel was the father of modern observational astronomy, and there is scarcely a department of the science that was not improved or perfected by him; and in mathematical astronomy his work was almost equally important Among other achievements, he added Bessel's Functions to the resources of the mathematical physicist, and he was one of the first (1823) to consider scientifically the personal equation of observers" (The New International Encyclopædia).

Bessel died in 1846

JEAN BAPTISTE BIOT
A Student of the Polarization of Light

THIS eminent French scientist, born in Paris on April 21, 1774, was educated for the army, and served in the artillery, but was led by scientific interest to leave the service and return to study at the Polytechnic School. In 1800, though only 26 years of age, he was appointed to the chair of physics in the College of France. He applied to Laplace for permission to read the proofs of his "*Mécanique Céleste*," and the introduction thus effected was the beginning of a close friendship which was very advantageous to both. Biot published in 1801 an "Analysis" of the great work of Laplace. An unprecedented shower of meteors having fallen at L'Aigle, in Normandy, on April 26, 1803, Biot was sent by the government to investigate the phenomenon; and in the same year he was associated in the study of gases with Arago and Gay-Lussac. In 1804 he accompanied the latter in his first balloon ascent, and was sent with Arago to Spain, two years later, for the purpose of measuring an arc of the meridian.

His most important work was connected with the study of optics His laborious and ingenious researches on the subjects of the polarization of light and of double refraction are embodied in many papers contributed to the Academy of Sciences. The most valuable discovery which he made was that of the rotatory action of fluids upon polarized light. He died on February 3, 1862.

JEAN BAPTISTE BIOT

Aside from a large number of scientific memoirs and biographies, Biot, who was an extremely prolific writer, published a number of works: one of them with Arago, "*Recueil d'observations géodésiques, astronomiques et physiques exécutées en Espagne et Écosse*" (1821); "*Analyse de la mécanique céleste de M. Laplace*" (1801); "*Traité analytique des courbes et des surfaces du second degré*" (1802); "*Recherches sur l'intégration des équations différentielles partielles, et sur les vibrations des surfaces*" (1803); "*Traité de physique*" (1816); "*Mémoire sur la vraie constitution de l'atmosphère terrestre*" (1841).

WOODWORK AND FITTINGS

The Choice of Wood Trim and Floors
and of Pots, Pans, and Utensils

SELECTION AND CARE OF WOODS AND METALS

THE number of woods and the variety of their finishes is almost bewildering, and the choice of one for any particular purpose and the cost and labor of keeping it in good condition are important considerations. Woods are classified as "hardwoods" or "softwoods." These names are somewhat misleading, as yellow pine (a so-called softwood) is harder than some of the hardwoods. The hardwoods are from broad-leaved trees, and the softwoods are from those with needle or scale-like leaves, such as the pines.

Wood for flooring must be even-wearing and free from slivers; it must take a durable finish and be attractive; and it must also be firm enough to bear the strain that it receives The hardwoods fulfil these conditions, but the softwoods are cheaper and therefore frequently used. Oak and maple are the hardwoods most commonly used; birch and beech to a less extent; while long-leaf pine and red spruce or Douglas fir are probably the most durable softwoods for flooring. Oak is frequently chosen for effect, and the quarter-sawed flooring not only shows up the beauty of the grain, but the boards are less likely to shrink or swell. Maple is hard, smooth and compact, and absorbs liquids slowly, especially if oiled, so that it is excellent for kitchen floors and others that have to be washed frequently.

For interior finish any wood can be used if previously well dried. Hardwoods as a class are liable to warp with changes in moisture and therefore are not so good as softwoods for door and window frames. The softwoods can be used as a core with a veneer of any other wood.

For furniture, the softwoods dent very easily and are not so satisfactory as the hardwoods. For kitchen utensils, dense woods which will not absorb moisture readily and the surfaces of which do not roughen easily — such as maple, beech, cotton-gum — are desirable. For chopping-boards, woods which will withstand hard cutting blows, such as elm, should be chosen. Elm is also good for drain-boards, as it endures soaking and scrubbing well.

After the wood has been selected it may be finished in a variety of ways. In order to make the color of the trim, window frames, doors, and floors harmonize with the walls of the room, or to darken the floor, paint is a very convenient finish. As it is opaque, it is useful for covering up wood with an unattractive grain or one with no very visible grain; and on a very old floor it can be used with good results.

Paint is essentially a mixture of linseed oil and a pigment or coloring matter, and white lead or other material to give "body." Linseed oil is used as the vehicle, because on exposure to air it absorbs oxygen (the process is also accelerated by the addition of certain substances called "driers") and forms a hard varnish-like film. Turpentine is a volatile liquid which is used as a thinner and also for the purpose of giving a "flat" surface. A painted floor forms a coat which is impervious to water and grease and can therefore be used in a kitchen, though it wears badly where it is much used. The United States Bureau of Standards recommends that three coats be applied to a kitchen floor.

Wood finishes: painting, oiling, staining, filling, varnishing and waxing

The first of these coats should consist of white lead in linseed oil with a little drier; the second of equal parts of white lead and zinc white in oil, coloring matter as desired, and drier and turpentine to give a flat surface, and the third of the same materials as the second except that the turpentine should be replaced by a good floor varnish. Each coat should be thoroughly brushed in and allowed to dry. It may finally have a coating of equal parts of turpentine and linseed oil rubbed in with a soft cloth and then polished with a woolen cloth to give a soft lustrous finish which will last longer.

Fresh coats of paint may be applied to a worn, painted floor, or the old paint may be removed and the wood refinished with paint or with any other finish. Old paint can be removed by scraping or planing. It usually pays to have this done by an expert workman. Household lye can also be used, but this darkens oak. The lye is best used mixed with hot boiled starch solution, using three tablespoons to a quart of starch. This softens the paint in a few moments, after which it can be scraped or rubbed off and the floor should then be washed, dried and sand-papered. All holes and cracks should, of course, be filled before the finish is applied.

Oiling was the method used by our ancestors for preserving their furniture even as far back as the Jacobean period, when poppy oil was applied and allowed to dry in for a day; the excess not absorbed was then wiped off and the surface was polished with wax applied with a woolen cloth. An oil finish on furniture requires repeated applications and plenty of rubbing, but it gives a very good, attractive finish which improves with time and attention.

An oiled floor is recommended for the kitchen, pantry and bathroom, as the oil makes the wood more nearly grease and waterproof. If applied cold, the boiled linseed oil should be brushed on lengthwise of the grain, rubbed in with a soft oily cloth and any excess wiped off with a dry cloth.

The first application of the oil will probably all soak in and a second coat can be applied. After drying for a few hours, it may be polished with a weighted brush covered with a clean woolen cloth. If applied hot, it may have one pound of paraffin wax added to every gallon of oil. This will sink in very much more easily than the cold oil. For pine floors, equal parts of oil and turpentine will penetrate better than oil alone, and leave a thinner film on the surface. Oiled floors, if the oil is not rubbed in well, will darken with use, as dust is apt to cling and unite with the oil. When dark and grimy, the old coating can be removed with lye (as previously described), and then the wood can be bleached with oxalic acid and thoroughly washed before the new finish is applied. It should be clean, dry, and free from dust when the oil is applied and can of course first be stained.

Oiled and painted floors are kept in good condition by sweeping with a soft brush or dry mop, or by rubbing with a cloth or mop slightly moistened with floor oil made by mixing one part of boiled linseed oil with three parts of turpentine. If necessary, they can first be cleaned with a soft cloth to which has been applied a little pure soap and warm water, but these should be used as infrequently as possible; soap or cleaning powders which contain alkali or abrasive must not be used White or light painted surfaces, such as doors, can be cleaned with warm water and a little mild, pure soap rubbed on gently with a woolen cloth. To avoid streaks which form if the water is allowed to drip down the paint, moisten from the bottom and work upwards. Rinse with warm water, keeping as dry as possible, and dry with a soft cloth. It must also be remembered that paint hardens with exposure to the atmosphere; new paint is therefore much softer than old paint and must be more carefully treated.

Staining a light colored wood floor is a convenient way of darkening it to give it the right color value, or of making a softwood take a tone similar to a hardwood. Stains can be bought ready mixed and are of two kinds: water and oil stains.

Water stains will soak in very readily and give a clear color and they are cheap, but sometimes they raise the grain of the wood necessitating further sand-papering. They can be used on both softwoods and hardwoods and should be applied thinly and evenly with the grain of the wood Excess should be wiped off at once with a soft cloth. A good water stain, particularly suitable for pine, is made by dissolving one ounce of permanganate of potash in one gallon of water, and the depth of color can be regulated by the number of applications. Oil stains do not give such clear colors and are not so good as water stains on hardwoods. Pine and maple floors should first be coated with floor oil and sand-papered before applying an oil stain, which can be allowed to set for a few moments before wiping off the excess. After staining, allow to dry for twenty-four hours, and polish with a weighted brush before using a filler, wax or varnish. Oak can be darkened by exposing it to the fumes of ammonia or by repeated applications of ammonia water.

The open-grained hardwoods, such as oak, walnut and ash, take a smoother wax or varnish finish if they are first "filled." Maple and pine do not require such treatment. The filling also makes the wood absorb less of the varnish or wax and so saves time, money and labor. A home-made filler can be prepared from cornstarch and whiting in the proportion of one part of either, or both mixed, to one part of boiled linseed oil and three parts of turpentine. This makes rather a light mixture and should be stained suitably to match the wood The oil tends to darken the wood and should be omitted if a light finish is desired. The filler is applied lengthwise of the grain with a stiff brush, allowed to set for a short time, then rubbed in with cotton cloth *across* the grain. A few days later it should be sand-papered down.

Varnish makes a smooth, hard, glossy finish on woods and is the one commonly used for softwoods. Varnishes are either spirit or oil varnishes. Shellac varnish is one of the former, being a solution of gum-shellac in alcohol.

There are two ways of using shellac: either alone on a floor, several coats being applied and each one except the last being sand-papered; or one coat can be used before wax is applied, though this is apt to make the wax finish more slippery. Oil varnishes are made from resins, drying oils, and volatile thinner (about 40 to 60 per cent turpentine or mineral oil). They dry more slowly but wear better than spirit varnishes. The spar varnishes, with a larger proportion of oil, are most durable and waterproof, and are good for kitchens and bathrooms. Varnishes containing much resin are usually inferior in quality and turn white with water.

Clean brushes must be used to apply varnish, and it should be brushed on lengthwise of the grain without allowing the strokes to overlap. Each coat should be allowed to dry two days.

If a varnished surface is badly worn or scratched, the old surface should be entirely removed. If only slightly marked, the scratches and white marks caused by water can often be removed by rubbing with kerosene, floor oil or linseed oil on a soft cloth. Ordinary care consists of polishing with a mop or cloth slightly moistened with floor oil or kerosene. Unless oil is used regularly, the varnish dries out and becomes brittle; but very little should be used on the mop, or the surface will collect dust and darken as a heavily oiled floor does. If exceedingly dirty, varnished floors can be wiped over with a woolen cloth wrung out of warm water with a little pure soap rubbed on it; this should be wiped off quickly and the surface repolished with the oiled mop or cloth.

Wax is a very good finish for hardwood floors. It preserves the color and enhances the beauty of the grain and improves with age. It requires, however, a good deal of labor to keep it in condition. Waxes dissolved in turpentine make the basis of all wax polishes. It is possible but not necessary to buy them ready made, as they can be made easily and successfully at home, and applied to unfinished woods, or woods which have already been stained, painted, varnished, or shellacked.

A simple wax polish can be made by dissolving two ounces of beeswax in one pint of turpentine. The United States Bureau of Standards gives the two following formulæ for floor waxes:

(*A*) 4 oz. beeswax 1 pt turpentine
3 oz. aqua ammonia (10% strength)
1 pt water

The wax should be shredded and dissolved in the turpentine, which can be warmed by placing in a pan of hot water (this must be kept away from a flame, since turpentine vapor is inflammable). When melted thoroughly, remove from the pan of hot water, stir in the ammonia and water, and beat until the mixture becomes creamy. This must be applied lightly and the excess wiped off at once if used on varnished

A WAXED OAK SURFACE

The left half has been cleaned by softening the old wax with gasoline on a cloth, rubbing with fine steel wool and rewaxing

or shellacked surfaces, as the ammonia dissolves varnish and shellac. It should then be polished with a weighted brush. If applied directly to an oak surface, the ammonia will help to darken the wood.

(*B*) ½ lb. beeswax ½ pt. raw linseed oil
1 lb. paraffin wax 1½ pts. turpentine

Dissolve the waxes in the turpentine and add the linseed oil, stirring vigorously. If applied to unfinished wood, the oil will be absorbed and will tend to darken it.

Success in waxing lies in applying a *very thin* coat with a woolen cloth, and allowing it to harden for some hours before it is polished with a weighted brush. If the mixture is too thick, it makes a sticky coating and is difficult to polish properly. Several coats should be applied to a newly waxed floor. The ordinary care consists of sweeping with a soft brush or dry mop.

Oil softens the wax and therefore should not be used. Once a week the floor can be wiped over with a cloth slightly moistened with turpentine or gasoline and repolished with a weighted brush. Marks and dirt will easily be removed in this way. Floors should not be rewaxed too frequently or too plentifully, as the surplus lies on the surface and is easily marked. The wax must be well rubbed into the wood by polishing, otherwise it looks greasy and unsightly and will remain slippery. If in very bad condition the old wax should be removed by rubbing with No. 1 steel wool dipped in turpentine or by sand-papering the surface after the wax has been softened by wiping it with a cloth moistened with gasoline or turpentine. It can then be wiped off with a soft cloth and the surface rewaxed.

The following recipe gives a softer wax polish that can easily be used on furniture:

1 oz. paraffin wax ½ pt turpentine
1 oz beeswax 1 tablespoon kerosene
3 tablespoons liquid ammonia (10%)

Dissolve the wax in warm turpentine; remove from the source of heat, and add the other ingredients, beating until the mixture is of a creamy consistency.

Linoleum floors wear well and require less attention if they are waxed instead of washed. When the linoleum is laid, it should be washed carefully with warm water and pure soap and then waxed and polished thoroughly. A liquid wax polish is easier to apply than a paste wax, but any good wax can be used. After the first application, it need only be treated daily with a dry mop, and polished with a weighted brush occasionally, renewing the wax every five or six weeks, and where traffic is greatest as often as required. Muddy footprints can be wiped off with a damp cloth. If used in a kitchen or pantry where washing is sometimes a necessity, water and soap should be used sparingly and the floor dried immediately. The polish can then be restored by rubbing.

Brushes used in varnish can be kept in the varnish. They should be chisel-shaped or slightly tapering and rather wide. They must be scrupulously clean and free from dust.

If used in shellac, they can be kept in the varnish or in alcohol. Brushes used in oil paint or stain may be kept wrapped in newspaper or submerged in turpentine or kerosene. If not to be used again shortly, the brush should be rinsed in turpentine or kerosene and then in gasoline; washed in warm soap-suds, rinsed in water, and shaken, and hung up to dry, bristles downwards. Brushes used in water stains can be washed in pure water.

Woolen cloths used for finishing and polishing can be cleaned by soaking in hot water with a little washing soda (3 tablespoons to 1 gallon). Stir occasionally with a stick; then wash in warm, soapy water and rinse with hot water which contains a few drops of kerosene. When not in use, cloths saturated with oil or wax should be kept in a covered tin to prevent spontaneous ignition or hardening by oxidation. Brushes used for waxing floors should be washed occasionally in warm water containing a little ammonia, rinsed carefully and then thoroughly dried in a current of air.

Unfinished wood should be washed with warm water and soap, using an abrasive such as fine sand; or an abrasive soap can be used if it does not contain any soda. Soda must not be used, as it discolors white wood. Rinse in warm water, then in cold, using water sparingly so that the wood does not become saturated. Dry quickly in a draught, but never near a hot radiator or fire.

Metals appropriate for household equipment and how to keep them clean

No one metal can be said to be good for all kitchen equipment; and for cooking utensils particularly, four points have to be considered: (1) Safety from poisonous compounds, (2) Ease of cleaning, (3) Economy in fuel, (4) Durability and suitability.

For frying, roasting and baking, iron or steel is undoubtedly the best material. Iron saucepans give excellent wear, but are heavy to handle, so are being replaced by lighter materials such as enamel or aluminum. They take up heat somewhat slowly, but retain it well. They are easily acted on by acids, so cannot be used for cooking acid foods. Steel, specially tempered, is used for making knives of all descriptions. The stainless steel and silver-plated knives are easy to keep in good condition. The great drawback to iron and steel is the ease with which they tend to rust in the presence of air and moisture. The process is really a chemical change taking place between the iron, the oxygen of the air and moisture, and the resulting product is ferric hydroxide of a characteristic red color. If either oxygen or moisture is kept away from the iron, this chemical reaction is prevented; and various devices — such as covering with paraffin wax, vaseline, oil or fat, black-lead, varnish and paint — are all practised with this idea in mind. More permanent coatings are given by covering the iron with enamel (enamel-ware), tin (tinware), zinc (galvanized iron), and nickel (nickel-plate). Once, however, these coatings are removed, be it only locally as by scratching, the iron underneath rusts very readily.

A GROUP OF TIN UTENSILS FOR THE KITCHEN

Other metals rust or tarnish more or less, but iron differs from most of them in that while the tarnish in most cases protects the surface beneath, when once the rust starts in iron, it proceeds rapidly and may cause corrosion throughout the material.

Tinned sheet iron and tinned wire are popular for many small utensils and are good as long as the surface is intact. The better tinware is retinned after shaping, in order to have a perfectly smooth and intact finish; but the coating on cheaper ware may be so thin that it gives little service before the iron underneath is exposed. Tin melts at a fairly low temperature so that an empty tin vessel should not be set in a warm place on the stove.

It is also acted on by hot acids and should not be used for cooking acid foods. Care should be taken that the wire meshes of sieves, etc are properly tinned if the sieve is to be used in contact with material which will be affected if the iron wire beneath be exposed

Zinc is not easily corroded and therefore *galvanized iron* makes a good sanitary covering for table tops and is used for sinks, pails, etc It is acted on by acids and alkalies and therefore cannot be used for cooking utensils.

Enameled sheet steel is now largely used for cooking vessels and enameled cast-iron ware for wash-basins and bath-tubs. Its surface should be free from blisters and cracks and have a smooth finish. It is frequently attacked more or less by acid foods and the surface is slightly roughened.

A GROUP OF ENAMEL-WARE UTENSILS

It is therefore best to avoid bringing it in contact with hot acid foods, and acids should not be used for cleaning enameled iron bath-tubs or sinks. A poor quality of enamel is not economical. Unless the enamel coating and the steel base of pans have the same coefficient of expansion, they will expand unevenly with heat and the enamel will chip. A thin coating of enamel chips with heat less quickly than a thick coating. Chipped enamel pans should not be used for cooking food, as the particles with sharp edges may get into the alimentary tract and cause trouble.

Nickel-plated fittings are usually made of brass coated with nickel. Nickel corrodes very slowly and the tarnish is not of a color very different from the metal itself.

Among the other metals encountered in household economy are *copper*, *brass*, and *bronze*.

Sometimes iron and steel "hardware" is given a thin coating of brass or bronze and may be represented to the buyer as being solid brass or bronze.

The actual material can be proved by scratching the surface. Solid brass fittings are very expensive. Copper is used for the bottom of wash boilers and kettles and is good for this as it conducts heat readily Copper lined with tin is used for the tubs of washing-machines and for boilers; and while tinned copper is used for some cooking utensils, it is expensive. Brass saucepans give excellent wear and if kept scrupulously clean, can be utilized for nearly all purposes.

Aluminum is extremely useful for saucepans, griddles, ladles, tea-kettles, etc., and if cast for these purposes, contains traces of copper to harden it. It is attacked very readily by brine and by alkalies, therefore cannot be used with these, or cleaned with alkaline compounds. It is agreeably light in weight.

Household silver can be either solid or plated, and as it is somewhat soft, great care must be exercised in washing and polishing not to dent it. If plated, it should have extra coatings on the parts most commonly in contact with other surfaces. The basis of silver-plate may be Britannia metal or German silver, both white alloys, so that there is not much difference in color when the plating is scratched; for knives and forks, a steel base is used.

When storing silver, each piece should be wrapped separately and wool should not be used, as it contains sulphur and this will gradually combine with the silver to form black silver sulphide. Tissue paper, green baize, or cotton cloth free from dressing are all suitable materials to use.

Iron utensils which are greasy should be washed with hot water and a *little* soda and soap. Frying pans can have the greater part of the grease rubbed off with paper before they are washed. Burned particles are readily removed from the sides of a saucepan with a saucepan brush after soaking for a short time. If necessary, pots and pans, oven sheets, baking tins, etc. can be scoured with a piece of coarse cloth dipped in sand or pumice powder and rinsed in clear water. They should be thoroughly dried before being put away.

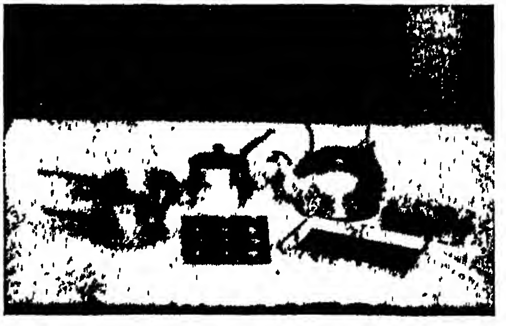
Ordinary steel knives should be washed carefully with hot, soapy water and then polished on a knife board or in a knife machine. Bath-brick can be used as the abrasive, though this is apt to scratch. Fine emery powder can also be used, but a very good material is Wellington Knife-Polish. Stainless steel knives do not require polishing in any way. All steel and iron utensils in storage should be protected from rusting by covering them with oil or saltless fat.

Tinned iron, nickel-plate and enameled iron must all be protected from scratches, so that only the mildest abrasive, whiting, should be used on them. Greasy tinware can be washed in hot water with soap and soda, but strong soda solutions should be avoided on enamel-ware. Burned food particles can be removed from enamel-ware by rubbing gently with crushed egg shell and salt, or with a very fine grit soap applied on the cloth Nickel seldom requires polishing if it is wiped with a cloth moistened with soap and water. To remove the light tarnish from the surface of galvanized iron is not economical, as it exposes a fresh surface. If very dirty, it should be treated with a cloth dipped in kerosene and then rinsed. To polish it and remove the tarnish, apply bath-brick and kerosene with a rough material or piece of carpet.

Copper and brass discolor very easily, the tarnish being dark in color, and in certain conditions a "verdigris" is formed which is poisonous. The tarnish is soluble in oleic acid ("red oil") and in hydrochloric and oxalic acid, but these latter attack the metal if left on for a time and are consequently not particularly suitable, except in cases of very bad tarnish, and then they must be quickly and completely removed. Most metal polishes contain oleic acid and another liquid such as kerosene with a suitable abrasive and perhaps a trace of oxalic acid. A good brass polish can be made by mixing two tablespoons of oleic acid with three of kerosene, adding enough rotten-stone or whiting to make a paste, and a *few* drops of oxalic acid solution. Whenever this or the preparations that are sold are used, the result is improved if the metal is finished with a cloth dipped in dry whiting to remove the last traces of the cleaning oil and so prevent rapid retarnishing. After cleaning brass and silver it is well to wash away all traces of the cleaning materials before final polishing.

Aluminum unfortunately scratches very easily and nothing harder than whiting should therefore be used as an abrasive — it is brightened by rubbing with finest steel wool and soap and polishing with dry whiting. A trace of acid (such as that of tomatoes or rhubarb) will also readily remove stains produced by certain foods.

Silver, both solid and plated, should be polished with whiting and denatured alcohol or ammonia. The principal care lies in washing thoroughly, before it is polished, in warm soapy water using a soft brush to get out the dirt and grease



A GROUP OF ALUMINUM UTENSILS

which lies in the corners and crevices, and in removing the whiting thoroughly (by again washing if necessary, or by using a soft brush) before giving it its final polish. Another method of cleaning flat silver consists in placing it in a hot solution of washing soda in water (1 teaspoon to 1 quart) in contact with a piece of aluminum. This makes an electrolytic cell, and the hydrogen generated is carried to the silver and reacts with the black silver sulphide or oxide and reduces it to silver. Oxidized silver cannot therefore be cleaned by this method. An aluminum pan should not be used in lieu of this piece of aluminum, as it will be attacked by the alkali and roughened and gradually worn away. This method does not produce such a brilliant finish on the silver, but it can be burnished by finally rubbing with a chamois skin.

GALILEO DISCOVERING NEW WORLDS

In the year 1609 Galileo made his first telescope at Padua, where he was professor of mathematics. He rapidly improved his instrument, and his discoveries in the year 1610 revolutionized all existing knowledge in astronomy. The discoveries of the satellites of Jupiter, the phases of Venus, the composition of the Milky Way, and the spots on the sun followed each other in quick succession.

OUR LONELY SOLAR SYSTEM

The Man who First Inferred that the Earth Moves Round the Sun, and the Man who First Saw that It is so

WILL THE PLANETS GO BACK TO THE SUN?

MANY and great universal questions have had to be dealt with before we could really be prepared to take any part of the universe by itself and consider it in detail. At the very least, we nust by now have adjusted our thoughts to the scale of the universe, and shall see things in their proportions. We are definitely in the third stage of theory of the universe, so far as sun and earth and stars are concerned The first imagined the earth to be the center of all things, and strove to explain the movements of the heavenly bodies in accordance with that idea. This we call the geocentric theory, and it was the basis of a system of astronomy known as the Ptolemaic astronomy, after its best representative. This followed the overthrow of Greek science, and was a clumsy attempt to make a system on a basis which the Greeks had long before seen to be false and had abandoned.

The step from the geocentric astronomy of Ptolemy to the heliocentric of Copernicus was the greatest in the history of this most ancient of sciences. We must not begin our account of the solar system without looking at the essential work of the Polish ecclesiastic Copernicus, to whom hitherto we have only just alluded; and thereafter we shall remind ourselves that, though the Copernican astronomy, which placed the sun and not the earth in the center of our system, is true, the heliocentric theory of the universe cannot be maintained, and we require to appreciate the third stage of thought, in which neither the earth nor the sun is at the center of things, and our utmost efforts fail to reveal any center of things at all, if such there be.

Copernicus was born in Poland in 1473. He received a thorough and comprehensive education at the leading universities of Poland and Italy, and having entered the ecclesiastical state, was made Canon of the Cathedral Church of Frauenburg. Though the duties of his various ecclesiastical offices occupied much of his time, his great book on "The Revolutions of Orbs" was completed in 1530, so that we are now nearing the end of the fourth century of the Copernican astronomy. For the first time since the Greeks, two thousand years before, it asserted that the sun and not the earth is the center of what we now call the solar system, and that the earth and the other planets revolve round it. The argument also asserted that the earth rotates upon its own axis. These are the essential contributions to knowledge made by Copernicus.

He had many difficulties to contend with, which we can realize only if we remember how little was then known. Not until a generation later was an infant to be born in Pisa who should invent the telescope, and not until twice as long a period had passed was Galileo's "old discoverer" to reveal the moons of Jupiter. The enormous importance of this discovery can be seen if we remember that the earth undoubtedly has a moon which revolves round it. At least the system made up of the moon and the earth is a "geocentric" one. But Copernicus asserted that the earth and Jupiter alike go round the sun; and it would have been a powerful argument to be able to point to a moon round Jupiter, showing the parallel between one asserted planet and another.

This argument in favor of the contention of Copernicus was provided by Galileo through his discovery of Jupiter's moons generations after the masterpiece of Copernicus was written. For he found four moons, evidently revolving round a central orb, sometimes eclipsed behind it, evidently controlled by it. Here, so to speak, was a small model of the solar system as Copernicus asserted it to be. Why should not the sun do with the planets what Jupiter does with his moons? This discovery then, besides being of great interest in itself, is of special historic significance in so far as it helped to make the new theories of Copernicus seem more plausible and secured for them acceptance by a larger number of scientists.

Posterity honors its great for what they did well, and forgives their mistakes

Copernicus declared that the planets, including the earth, move round the sun in circular orbits. Their orbits are, indeed, not far from circular, but the difference was enough to provide Copernicus with very serious difficulties, which he did his best to surmount, arguing that the planets are checked at times in their flight, so as to account for their appearance where, on the theory of circular orbits, they were not expected to be. We already know that the difficulty arose from the naïve assumption, as it now appears to us, that the orbits of the planets must be circular, the circle being the only perfect figure. But, indeed, it would have been more than one man's work to do all that Copernicus did, and also to undertake the long and complicated calculations which were Kepler's life-work, and enabled him to show that the orbits of the planets are ellipses. Though much that Copernicus taught was wrong, he did his share of adding to the world's knowledge.

It is a fact worth noting that the revolutionary views — as they may be doubly called — of this son of the Church gave no offense to its prelates. On the contrary, it was Luther who objected to them. Copernicus himself ever enjoyed the esteem and affection of his ecclesiastical superiors, and was encouraged to publish his great work which, when it finally appeared, was dedicated to Pope Paul III. It was only later on, when Bruno and Galileo injected a theological aspect into their new astronomical teachings, that the opposition of the Church was temporarily aroused.

The amazing isolation of our earth and its solar comrades in lonely space

The Copernican astronomy teaches us to look upon the sun and its planets as a system, in some measure apart, which we call the solar system, from the Latin name of *Sol*, the sun. And here we make a discovery that is better made now, when we are convinced that the universe is a universe, and have clear evidence of the working of such laws as those of motion and gravitation, by which all the heavenly bodies are bound together This discovery is that the solar system is amazingly isolated in space

There is no star, nor star-cluster, nor constellation near enough to have any measurable influence upon the solar system. It is like an island group in an immense ocean; we are almost tempted to say, in the center of an immense ocean, and the evidence for and against that view will indeed require to be considered. The sun is certainly one of the millions of stars, but it is extraordinarily remote from the multitudes of stars, and even from its nearest stellar neighbor. When the theory of Copernicus was suggested, and Kepler had advanced it by his laws of planetary motion, and Galileo's telescope had supported it also, in the manner we have seen, astronomers protested that, if the earth really revolves round the sun, at a distance of many millions of miles, the position of the stars should seem different at different times of the year — the constellations should be of a different shape when viewed from opposite sides of so great an orbit.

The pioneers all declared that the stars did not appear to alter their relation to each other, not because the earth did not indeed move through a great distance, but because the distance of the stars from the earth is so huge that the whole orbit of the earth is a mere point in comparison.

remembered in our speculations yet. It is that some dark stars may be nearer to us than the nearest bright ones we know, and that these dark stars may have a motion, or one of them may have a motion, which is bringing it towards the sun In the course of time such a star would affect the movements of the solar system, and its existence and approach could be detected by astronomers That, also, is a matter for future consideration; but, meanwhile, when we admit the isolation of the solar system, we are bound to add that we are assuming the non-existence of dark stars in our nearer neighborhood. However, there are none such at present near enough to affect the motions within the solar system to any measurable degree.

The modern calculations of astronomy thus entirely justify the feeling of poets, and lovers, and philosophers in all ages, that the stars are terribly remote, and utterly without concern for human joy and sorrow. Such reckonings conversely dispose of the astrologers' idea that the stars have immediate influence upon men. That view is proved absurd by the modern study of the isolation of the sun, and the wisest of the past have always known it. Thus Shakespeare speaks what he himself believes when he says:

> Men at some time are masters of their fates;
> The fault, dear Brutus, is not in our stars,
> But in ourselves, that we are underlings.

The awful splendor of the everlasting calms of space between the stars

And the philosophical view, now verified, is nowhere better expressed than in the words which Tennyson puts into the mouth of Lucretius, the Roman didactic poet who 2000 years ago wrote his famous work "On the Nature of Things":

> The lucid interspace of world and world,
> Where never creeps a cloud, or moves a wind,
> Nor ever falls the least white star of snow,
> Nor ever lowest roll of thunder moans,
> Nor sound of human sorrow mounts to mar
> Their sacred everlasting calm!

Such is the just view. It is awful, but it is splendid. It needs repeated and various assertion in these days, when a strange recrudescence of superstition is to be found even in the "educated" classes, and when men and women daily consult astrologers, and have their horoscopes read, and marry or commit suicide on account of what they are told It is time to have done with such things, and vastly better to accept the truth as science demonstrates it today. Psychical and spiritual forces there may and must be, which science cannot reckon with nor deny, but not the influence of those incredibly remote masses of matter — they are no more than that — which we call the stars.

The solar system, then, is alone in the world at present and it hangs together, like a little universe, in virtue of the laws of gravitation and motion; in virtue, also, we must add, of its origin in a single object, from which it has derived the arrangement of motions that makes its balance possible. Thus, to take only one instance, the planets all travel in the same direction. Moving at different rates they may overtake one another, but they never meet and pass one another like trains on opposite lines. The system could not persist in such a case.

The irony of a mocker of perfection turned by all we know into sober truth

Thus we have to reckon with not only the laws of gravitation and motion, but also the original disposition of the parts of the solar system, and the common origin of the motion of its parts, before we realize why it holds together as it does. And, so far as the present state of things is concerned, we may almost accept the half-ironical words of Carlyle at the beginning of "Sartor Resartus": "Our Theory of Gravitation is as good as perfect: Lagrange, it is well known, has proved that the Planetary System, on this scheme, will endure forever; Laplace, still more cunningly, even guesses that it could not have been made on any other scheme." We shall find facts which Lagrange had not reckoned with, nor Laplace either, but the laws of gravitation and of motion are not "as good as perfect," but perfect; and they permit us to study the solar system, provisionally and in the first place, as a stable and permanent object, whatever its origin and destiny.

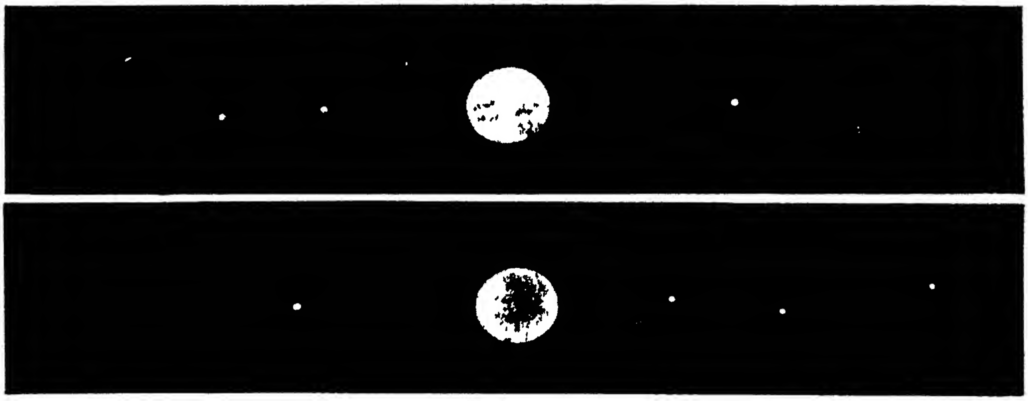
An analysis of all that makes up our self-contained and isolated solar system

What, then, does this object consist of? Let us make a list of its items — a census of the universe within a universe, to which our earth belongs. There is, first, the sun. We may call it, for convenience, the center of the system, if we remember that it is not in the center of anything, but in one or other focus of the ellipses which the planets describe round it.

In another sense the sun may be the center of the solar system, for probably it is the "center of mass" or "center of gravity" of the system, and represents today the center of gravity of the nebula from which we presume the solar system to have been formed.

Next there come the major planets, or satellites of the sun. Some of these travel in orbits inside that of the earth, and others travel in orbits outside the earth's. Then there are the minor planets, many hundreds, perhaps thousands, in number; for 957 of them had been individually discovered and catalogued up to the year 1920, and others are still being discovered. Some of them have names, but most of them have only numbers. Many of these minor planets are far smaller than the moon. Nevertheless they are planets, traveling in elliptical orbits round the sun, as the earth or Jupiter does. The moons of those planets that possess them furnish a further group in our list. They are satellites of the sun, for they undoubtedly travel round it, but they are also satellites of the sun's satellites; and their actual course in the sky, unlike the regular, forward, curved path of a planet, is extraordinarily complicated, combining motion round their "primary," as their planet is called, with motion round the sun. Though they may be much larger than many or any of the minor planets, their position in the solar system is clearly secondary.

Sun, planets, major and minor, and their satellites, constitute the more evident parts of the system But comets have to be included, though so very different in form and size and composition. Here the numbers must necessarily be vague. We can say that there are eight major planets, with not less then twenty-six satellites between them, and not less than nine hundred minor planets or "asteroids." These all definitely belong to the solar system. The same may be said of not less than thirty comets, each of which moves in a known elliptical orbit. They may be a very long time, even three-quarters of a century, in returning to the sun, but they do return, as we know both from actual observation of many, and, in the case of others, by the fact that the elliptical character of their orbits can be proved. But other comets appear to move in paths of another kind. Instead of moving in any closed curve, like an ellipse, which returns upon itself, they seem to move in paths which are open, parabolas or hyperbolas.



JUPITER AND ITS MOONS AS GALILEO SAW THEM

When Galileo first looked at Jupiter through a telescope on January 7, 1610, he saw that it was a globe having three moons, two on the left and one on the right, looking again on January 13, he saw four moons, one on the left and three on the right, and this revealed to him the new fact that the moons were revolving round Jupiter Jupiter's moons can be seen through a good field-glass.

so that they pass round the sun once, and are never expected to return Such comets would dash away beyond the outer limit of the solar system, though with steadily decreasing velocity, in consequence of the sun's retarding influence upon their flight away from it; but if their paths were really not elliptical, they could not return, but would move on until they came under the influence of another sun, which they might visit similarly. Of such comets the amazing words might be said, they go from star to star; visiting and twice passing through the system of one star after another. If such were the case we could not reckon them as really members of our solar system.

But, as we shall see later, it appears more probable that the views on this subject, hitherto accepted, are erroneous. Probably the paths of all comets are elliptical. They do return to the sun, and are as truly members of the solar system as the earth is. But they may move out immeasurable distances into space, far beyond the orbit of Neptune, before they begin the return journey, and the mere span of human observation and record may be pathetically inadequate for the proof of their return. Thus we cannot say at all how many comets may be in space, some traveling towards, some traveling away from the sun, but not yet seen. If we were to be strict in our definition when asked the dimensions of the solar system, we should have to state not merely the diameter of the orbit of Neptune, but a figure wide enough to accommodate the orbit of whatever comet, known or unknown, travels furthest from the sun. If we reject the idea of comets which never return, we may probably also reject that of comets which have approached the solar system from outer space and have then been "annexed" by the sun. It seems more likely, though it is by no means certain, that all the members of the solar system are original members, and that none of the sun's family belong to it merely by adoption.

VENUS REVEALED AS A PLANET

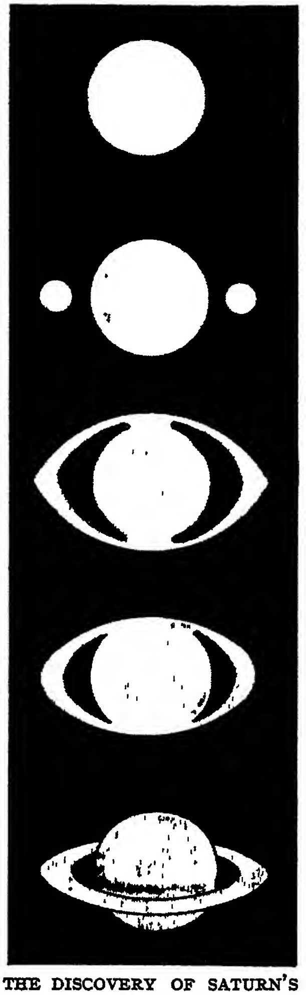
Before September, 1610, all men believed Venus to be an ordinary star, designated in a conventional way at the left of the figure, but at that time Galileo's telescope showed it as a half-moon, proving it to be a sphere lighted by our sun

Meteors or shooting-stars must be included also in our list of the solar system. The numbers here are enormous, and cannot be entered, even approximately, in our census We shall learn later that these bodies have a historical relation to comets, and some of them travel in paths similar to those of comets, or in paths which were formerly followed by comets. As meteors reach our earth they seem to come from all directions of space, quite irregularly. Others, again, appear to come from the direction, though not from the distance, of certain constellations, such as Leo and Perseus, and are called the Leonids or Perseids accordingly Since they are often called shooting-stars, this name, and their association, apparently in place and also in their special designations, with real stars, often confuse people. But meteors are not stars, and have nothing to do with stars or constellations. Notwithstanding their apparent irregularity of motion when they reach the earth, they are true satellites of the sun, and just as definitely members of the solar system as the earth is They have their own orbits, as the earth has, and their passage into our atmosphere is dependent on the fact that the earth's orbit and theirs intersect and that at times the earth and meteors come to the common point of their two orbits at the same time. This will be enough to establish our present point—that meteors are indisputable parts of the solar system, and must be included in any catalogue thereof.

A vast multitude of bodies which must be very like meteorites constitute the famous rings of the planet Saturn. They are not moons—of which Saturn has an abundant supply as well—and they are not included under meteors in general. These also, however, are part of the solar system.

Great quantities of matter in finer form must also exist in the spaces between the planets. It is so fine that we might compare it to dust, and "cosmic dust" is the name by which the astronomers know it.

This material must presumably travel in orbits round the sun, if it is not to be drawn into the sun by gravitation. The discovery of radiation-pressure complicates the case, however, and may serve to keep cosmic dust away from the sun, even apart from any orbital motion, such as keeps the planets from being drawn inwards This cosmic dust seems trivial, but is not so For one thing, it may be derived from the mutual clash of meteorites, and may thus be really of cometary origin, as meteorites seem to be. But it is also important because its presence in space, between us and the stars, rather complicates our problem of seeing the stars If there be much of it, and especially if any cosmic dust exists in the vast spaces between the solar system and the stars, evidently some of the light of the stars will be absorbed as it passes through space Now it makes a profound difference to astronomical calculations, and above all to the question of the limits of the stellar universe, whether or not there is absorption of light in its passage through space. If such there be, then the gradual thinning of the stars, as we pass outwards through the universe, is in part only apparent; if there be no such absorption, the thinning of the stars and their ultimate absence from space beyond a certain distance, or in certain directions, is real, and means that, in such cases, we have really got beyond the universe of stars to which our sun belongs. These are questions now in controversy, and they must be duly considered when we have to study the starry universe; meanwhile we must note that "cosmic dust" does exist, and that what we know of it at first hand — for some of it reaches the earth — shows that it must certainly be included as part of the solar system



THE DISCOVERY OF SATURN'S RINGS

The four upper pictures show how Saturn appeared through Galileo's imperfect telescope, causing much speculation and mystery The bottom picture shows the clearer view obtained in 1656 through the more perfect telescope constructed by Huygens

In this catalogue of the solar system, which includes the results of the present century's work, and is the most comprehensive yet published, we must include countless billions of particles smaller than those of cosmic dust, smaller even than the very atoms of matter. For we have lately learned that the sun, like other radiant bodies, is constantly shooting forth from its surface a stream of electrons, electrified particles, vastly smaller than atoms, which fly outwards through the solar system at vast speeds, and many of which strike the earth's atmosphere Their production by the sun varies in intensity at different times, but they are continuously produced, and are certainly part of the solar system, though we cannot yet trace the destiny of those — doubtless immeasurably the greater number — which do not strike any planet in the course of their outward flight. It may be that ultimately, in obedience to the law of gravitation, they return to the sun; but it is imaginable that they may travel so fast as to pass beyond the range of its influence, and so be lost to the solar system forever. But until they do so — if they do so — they are parts of it.

All the members of our catalogue up to this point undoubtedly exist. But we must also mention two supposed members of the solar system, one of which, no longer believed in, has actually received a name. Remembering how difficult it must be to notice a small planet very near the overwhelming brilliance of the sun, we may surmise the existence of a planet whose orbit is inside that of Mercury, the known planet nearest the sun.

The name of Vulcan has been given to the supposed intra-Mercurial planet Observers have supposed that they have seen it in transit, as a dark object, across the face of the sun, as Venus or Mercury may be seen. Others have supposed that they have seen it during a total eclipse of the sun, when a small planet near the sun would have a chance to show itself But the general belief among astronomers now is that the modern Vulcan is but a dream of the imagination

NICOLAS COPERNICUS

Much more recently, and indeed at the present time, astronomers are asking whether there may not be a planet outside Neptune, which is the known planet furthest from the sun. Just as peculiarities in the movements of Uranus, its inner neighbor, led to the discovery of Neptune, so peculiarities in the movements of Neptune might lead to the discovery of an outer neighbor.

But, of course, such inquiries must demand much time. Neptune takes nearly 165 years to complete one revolution round the sun That is the Neptunian year But the eye of man only recognized the planet, for the first time, some seventy-six years ago, namely, in 1846, so that Neptune has not yet completed half a journey round the sun since its discovery. The discovery of a new planet might extend the bounds of the sun's kingdom by as mighty an area as did that of Neptune itself Failing Vulcan, and this unnamed and hypothetical planet beyond Neptune, our catalogue of the solar system is now complete, if we allow for the not unlikely discovery of more moons, such as the present century has already added to Jupiter, and of more asteroids or minor planets and comets.

The list of the planets, in order outwards from the sun, will thus run, Mercury, Venus, Earth, Mars, minor planets, Jupiter, Saturn, Uranus, Neptune. The task now before us will be to investigate how this system of bodies came into being, or even how any of its individual members may be supposed to have come into being. This is the problem of planetology, or the birth of planets, which foreshadows the more stupendous problem of the birth of suns or stars. Then we must ask ourselves what changes are now occurring, if any are, to produce a different solar system in the future, or to end its history altogether — changes great and steady, not merely the diversion of a comet from its ancient orbit by the gravitational force of Jupiter, or any such local, if remarkable, occurrence. And then we have to ask a wholly distinct but no less important question — the whence and the whither, in universal space, of the solar system.

Meanwhile our problem is not an impossible one, in some degree, for we have an isolated system to study — a little universe which is comparatively small, and so accessible to our telescopes that at least one moon of the remotest of the planets can be detected. Compared with any system round a double star, ours is thus more easily understandable, and evidently single and orderly.

METALS THAT SEEK A MATE

How the Alkaline Metals, by Clinging to Others and Changing Partners, Build Up Life in Plants and Give Stability to Animal Frames

FROM SEA SHELL TO MILAN CATHEDRAL

WE have considered the properties and uses of some of the chief metals, such as iron, aluminum, gold, silver and mercury, and we now come to describe two important groups of metals, known as the alkali metals and the metals of the alkaline earths, both of which have played an important part in the development of applied chemistry, and are the basis of a huge industry.

The metals sodium, potassium, lithium, cæsium and nebidium take the group name "alkali" from the Arabic words *al qali*, the ashes of a certain plant. The initial letter of the latinized form of this arabic word, *Kalium*, is used as the chemical symbol for potassium and curiously enough this latter name is only the latinized form of the English "potash" All the metals of this group resemble potassium, "the alkali metal," in physical and chemical characteristics.

The second group, metals of the alkaline earths, comprises calcium, barium, strontium, beryllium and usually also magnesium The compounds of these elements with oxygen have a low solubility and other earthy characteristics, and as they also have a distinctly alkaline reaction, the elements are called metals of the alkaline earths.

The typical alkali metals sodium and potassium were discovered by Sir Humphry Davy over a hundred years ago. Together with the other members of this and those of the second group, sodium and potassium are never found free in nature but always in combination with other elements. Regarded as metals, they are very poor specimens of their class: they have little luster, they have hardly any tenacity or ductility, they are lighter than water, and they are so soft that they can be kneaded with the fingers They certainly cannot be used for purposes for which other metals are used: we cannot make knives or forks of them, or even bracelets and ornaments.

Further, they have such a craving for oxygen and hydrogen that they clutch both whenever they get a chance, and become transformed into compounds unlike their real pure selves. So fond are they of hydrogen and oxygen that if a piece of potassium be put into a basin of water it will rush about over the surface, tearing the particles of water in pieces to get these elements for itself, and by the very force of its efforts will create enough heat to set the freed hydrogen on fire—enough heat, that is to say, to enable all of the liberated hydrogen to join the oxygen of the air and form water again. Sodium is not quite so ardent, and will not set the hydrogen on fire unless the water be heated, or unless its motion be checked, but it, too, has a great craving for hydrogen and oxygen.

Sodium is one of the most universally distributed, perhaps the most generally distributed, of the elements. It is never found free, but always in combination, chiefly as common salt. If it occurred free, it would be a very active element indeed, but its very activity must have given it a very brief unwedded life. It is best known in its combination with the gas called chlorine, when it forms the substance known as common salt.

There are calculated to be 14,000 million million tons of salts in the sea, or about fourteen and a half times the bulk of the entire continent of Europe above sea-level. If this amount of salts could be spread equally over the bottom of the sea, it would cover it with a deposit of strata about one hundred and seventy feet deep. It has been estimated that about 77.75 per cent of these ocean salts consist of sodium chloride.

Besides this, enormous amounts of rock-salt deposited from the sea occur in various parts of the world. The salt mines of Wieliczka, in Austria, have been worked for more than six hundred years, and extend six miles in length, two miles in breadth, and have reached a depth of 1200 feet. Not only is salt found in the sea and on the land in these vast quantities, but it is present in infinitesimal amounts practically everywhere; and one of the difficulties of spectroscopic analysis is due to the ubiquity of salt.

It seems most providential that sodium and chlorine occur combined in such quantities, and have such affinity for each other. If there had been no chlorine to combine with the sodium, the sodium would have stolen a great part of the atmospheric oxygen; and if there had been no sodium to combine with the chlorine, a suffocating gas with an unpleasant odor, poisonous to all animal and vegetable life and a bleacher of all colors, the chlorine would have rendered the world a lifeless gray desert. As it is, in combination the two elements are not only harmless to life, but essential to it. In the salty sea-water animal and vegetable life probably began, and blood of all animals and the sap of all plants contain salt, and it is probable, almost certain, that without salt no life could be. Certainly sodium and potassium salts play a very important part in stimulating the action of the heart of animals. Harvey, for instance, when he was experimenting on the heart of animals, found that a heart which had ceased beating would begin again if he touched it with his finger moistened with saliva, and the salts of sodium and potassium in the saliva were the stimulant.

The part played by salt in the realities of health and fallacies of the credulous

As an article of diet, salt is of considerable importance. Only animals that live on raw meat can dispense with it, and as soon as man became civilized enough to cook his meat and to eat cereals salt became a necessity. In ancient days it was not so readily obtainable as now, and many phrases and social customs and religious rites testify to the high esteem in which it was held. In the offerings to the ancient gods salt was always included; and when the superstitious person nowadays throws a little salt over his shoulder to propitiate the fairies, he bears testimony to the vitality of old tradition.

Sodium occurs also in the form of sodium carbonate, sodium bicarbonate, sodium nitrate, caustic soda and sodium sulphate. The carbonates are found in various mineral springs, and there are enormous deposits in Wyoming, California and Nevada. Owen's Lake, in California, is estimated to contain from twenty to forty million tons of the carbonate.

How the Chile nitrates were formed and preserved for us

Sodium nitrate is probably the most important compound of sodium except the chloride. Its importance is due to the fact that for the past hundred years or more it has furnished most of the world's nitrogenous fertilizer, and almost all of its nitric acid. It is found almost exclusively in the Pampa de Tamarugal, a broad desert plateau in the north of Chile, between the Andes and the coast hills, and it is therefore known as Chile saltpeter. It has been formed during countless ages by the labor of "nitrifying" bacteria, which acted on decaying sea plants left there when the mountains of Chile were raised from the ocean in some prehistoric upheaval. Only the fact that the region is entirely rainless has preserved the nitrate and prevented it from being washed into the sea, as would normally be the case, for it is very soluble in water. Every year from two to three million tons of saltpeter are exported from Chile.

How civilization will continue to depend on a large supply of nitrates

Strangely enough, of all the things which have united to make possible the continuance of our civilization, the two most important ones are derived from sodium nitrate During the Middle Ages civilization again and again found foothold in some one part of the world, but as soon as a nation began to devote most of its time to intellectual pursuits, some hardy, savage tribe would swoop down upon it and wipe it out. The one thing which changed all this was the discovery of explosives, and the advantage their use gave the civilized nation over the savage tribe. Explosives have, moreover, made possible our roads, canals, railroads and bridges, without which civilization could not have progressed half as rapidly as it has The importance of sodium nitrate in this respect is due to the fact that without nitric acid, or nitrates, no explosives could be made.

But even more important for the welfare of civilization is the maintenance of an adequate food supply. In former times the increase in population in some parts of the world has been counterbalanced by the opening to cultivation of enormous areas of virgin soil. But now the population and the per capita food consumption is increasing more rapidly than ever, while but little new land is available Due to improper farming methods, much of our agricultural land is well-nigh exhausted, and unless radical steps are taken, the world's food supply will soon be inadequate. The prevailing high prices of foodstuffs give warning of the time when an actual shortage will exist.

For this condition of affairs, but one remedy can be found. The only reason a soil can cease to yield good crops is that its supply of phosphorus, potassium or nitrogen is exhausted, and these three substances may be added without great expense in the form of fertilizers. Part of these needed elements is frequently supplied by barn-yard manure, wood ashes, slaughter-house refuse, fish scrap, cotton-seed meal, etc It is frequently found better, however, to add these elements in the more concentrated form of salts — the potassium being supplied in the form of potash (which will be mentioned later), the phosphorus as phosphate rock, and the nitrogen as sodium nitrate, or sometimes ammonium sulphate

The importance of nitrogen in fertilizers

Of the three necessary elements, nitrogen is at once the most necessary, the most expensive, and the one whose supply is the most nearly exhausted. Strange as it may seem, while a plant builds up most of its structure from carbon dioxide, a gas of which there is but three-hundredths of one per cent in the air, it is totally unable to make use of the nitrogen which composes nearly 80 per cent of the air. In fact, every square yard of soil is pressed down by a column of nitrogen weighing about $7\frac{1}{2}$ tons. It is true that some plants, such as peas, beans and clover, can indirectly use the nitrogen of the air, but only because certain bacteria on their roots convert the atmospheric nitrogen into a more available form.

The civilized world cannot live on peas, beans and clover, however, and therefore the deficiency of nitrogen for the other crops must be supplied by the liberal use of sodium nitrate or some other nitrogen compound As we have seen, however, this sodium nitrate can only be obtained from a certain region in Chile, and the supply is rapidly being exhausted, since it is in demand for both explosives and fertilizers.

The fixation of nitrogen

Scientists have for some time realized the necessity of finding new sources of nitrogen. The first possibility which suggested itself was to find some substance which would combine with a small part of the billions of tons of nitrogen in the air and make it available for plant food. Such a conversion of free gaseous nitrogen into a solid or liquid compound is known as "fixing" the nitrogen, and the processes used are referred to as "nitrogen fixation processes."

Now, while oxygen, the other principal constituent of the air, will combine very readily with an enormous number of substances to form such solid or liquid compounds, nitrogen is so inert, so unwilling to join hands with other elements, that it was for a long time thought impossible to make any nitrogen compounds from the air except by a few extremely expensive processes. Attention was therefore turned to the supply of nitrogen in coal, part of which is converted into ammonia whenever coal is burned. While it is impossible to save any of this when coal is burned in the open, it was found that large quantities could be recovered in the manufacture of coke and gas. All modern coke and gas plants are therefore of the "by-product" type, and the profit from the ammonium sulphate thus secured has brought about a revolution in the coke and gas industries. As the world has continued to grow, however, even the millions of tons of ammonium sulphate thus produced have proven inadequate to meet the growing demands for nitrogenous fertilizer, and the price has remained so high that farmers could not afford to use it in proper quantities. Even now our crop production is suffering greatly in consequence of this high price of nitrogenous fertilizers.

Science and preparedness

Meanwhile scientists have continued to experiment, hopefully, though often with little encouragement, trying to find practicable methods for making nitrogen compounds from the air. Success was finally attained, however, and the past decade has seen the development on an industrial scale of three types of fixation processes. As an illustration of the benefit which comes to a nation which fosters scientific research, attention may be called to the fact that Germany would not have been able to hold out more than a year in the Great War had it not been that she was able to make from the air both the nitric acid needed for her explosives and the nitrogen compounds for her fertilizer, thus preventing a veritable famine both of food and munitions.

It will be seen as we consider the various processes, that all involve the use of extremes of temperature or pressure, these conditions being necessary in each case in order to make the inert nitrogen combine with anything else. It is this necessity for using violent methods which delayed the development of processes for so long, and makes them so expensive even now.

The arc process for nitrogen fixation

The most direct method of making nitric acid from the air is by the arc process. This consists essentially in burning the nitrogen of the air with oxygen. In order to bring this about, air is passed through an electric arc, which gives the highest steady temperatures known on this planet. This causes about 2 per cent of the nitrogen to unite with oxygen, forming nitric oxide, another colorless gas. This is rapidly cooled, oxidized further to nitrogen peroxide, a reddish brown gas, and finally absorbed in water to form dilute nitric acid. Several types of arc processes are used, but they differ only in the kind of electric arc employed, and the method of heating and cooling the gases. They all consume such large amounts of electric power that they can only operate in places like Norway and Iceland, where electric power from waterfalls is very cheap.

The cyanamide process

The process which is at present operated on the largest scale is the cyanamide. It was developed in the early part of this century by Frank and Caro in Germany. In this process lime and coke are heated to a very high temperature in an electric furnace. This forms calcium carbide, a grayish substance which is well known because it can be made to generate acetylene by adding a small amount of water. This calcium carbide is then further heated with some nitrogen from the air, and forms calcium cyanamide, familiarly known as "cyanamid" or "lime nitrogen." This valuable substance can be used directly for fertilizer with fairly good results.

It is, however, more often heated with steam under pressure to form ammonia gas, which may be converted into ammonium sulphate or other substances used in fertilizer, or it may be oxidized to nitric acid by the Ostwald process, which, developed by Professor Wilhelm Ostwald in Germany, consists essentially in passing ammonia gas and air through a woven platinum gauze, which acts as a catalyzer for this reaction This produces nitric oxide, which may be converted into nitric acid as described under the arc process. Although the cyanamide process is thus seen to be rather complicated, it is probably the cheapest one which is now being operated, though recent improvements in the Haber method make the latter a real competitor.

Boiling a liquid at 300° below zero

The Haber process in principle is far simpler than the cyanamide, but it is very difficult to carry out on a large scale. Air is compressed and cooled until it forms liquid air, and the nitrogen is then boiled off at a temperature about 300° below zero, leaving the oxygen behind. This nitrogen is further purified to free it from the last traces of oxygen. Pure hydrogen is then prepared by compressing, cooling and liquefying out all the other gases from producer gas. The hydrogen and nitrogen are then mixed, compressed to a pressure of 2000 or 3000 pounds per square inch, and heated to about 1100° in steel containers. As may well be imagined, the construction of apparatus to hold gases under these conditions is very difficult, and the operation itself is rather dangerous. It results, however, in the formation of a small amount of ammonia, which is separated out by liquefaction.

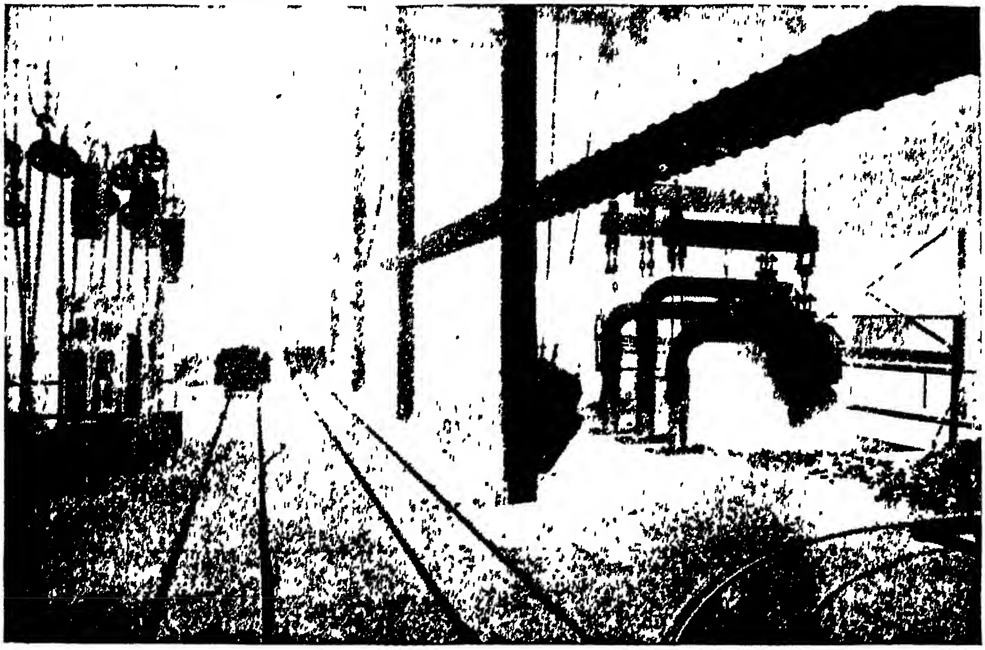
These are only the three most important processes out of half a hundred ways which science has found to fix atmospheric nitrogen. Most of them are still too expensive to compete with Chile saltpeter, but the processes are rapidly being perfected and cheapened, so that the world need no longer fear a nitrogen famine, and may hope to see a marked increase in our food supply within a few years.

The United States waking up to the importance of nitrogen fixation

Although most of the European nations, Canada, and even Japan, had established the nitrogen fixation industry within their borders prior to the war, the United States had done practically nothing in this direction until war-time needs forced her to awake to its fundamental importance to our national security. Throughout the war, and for several years thereafter, the War Department and the Department of Agriculture kept a large staff of highly trained men at work on the fundamental problems of nitrogen fixation and, in addition, financed the tremendous development of water-power and fixation plants at Muscle Shoals, Alabama, as well as one or two smaller plants in other parts of the country. One of the Muscle Shoals plants was designed to operate on the cyanamide process, and one on a modification of the Haber process.

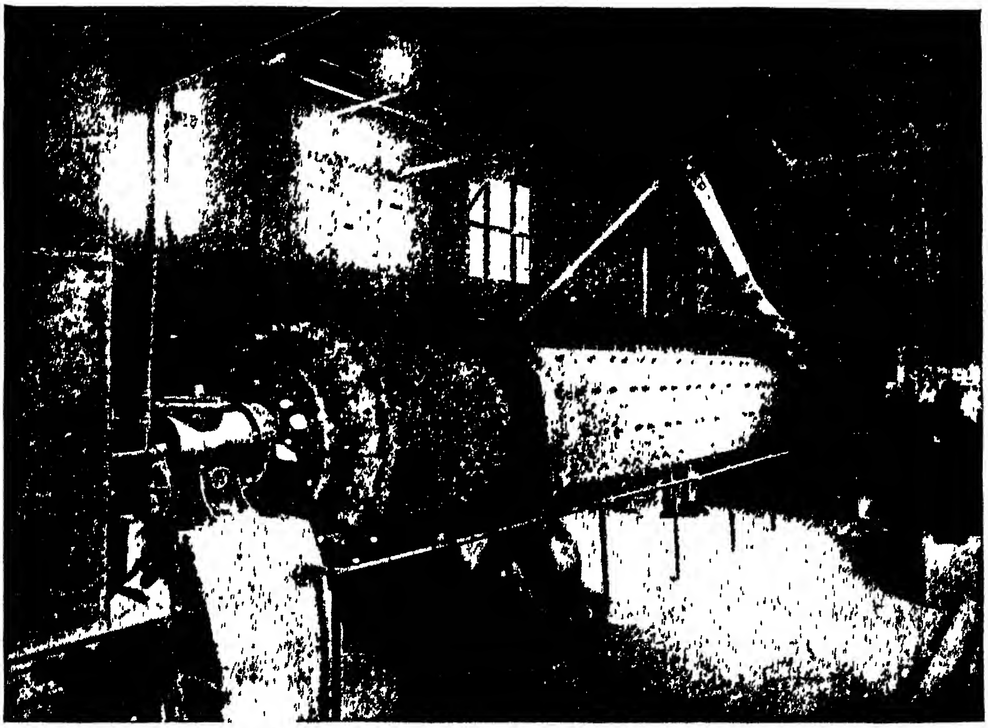
As indicated by the previous discussion, cheap power is the prime requisite in practically all of the fixation processes and only the development of large sources of water-power, such as that at Muscle Shoals, can make possible the commercial success of nitrogen fixation industries in times of peace. Since the main cost of water-power is in the interest on the investment in dams, locks and machinery, the government, which can borrow at low interest rates, can produce power much more cheaply than any private industry.

Unless the government does take steps to insure the development of nitrogen fixation industries even in times of peace, or at least to maintain large plants in condition for immediate operation, a war with a foreign power might cut us off from our supply of saltpeter. We should then be unable to make enough explosives for our guns, and without explosives, guns, battleships and even armies would be entirely useless. In addition to these considerations, the nitrogen fixation industry is worthy of government support in its initial stages of development because of the possibility of greatly cheapening and extending the use of the important nitrogenous fertilizers.



CARBIDE FURNACE

Here lime and coke are fused by a powerful electric current, at a temperature of 4000° F, forming calcium carbide The carbide from the furnace is tapped into iron cars, like small coal trucks, and allowed to cool in the cooling sheds.



Courtesy American Cyanamid Company

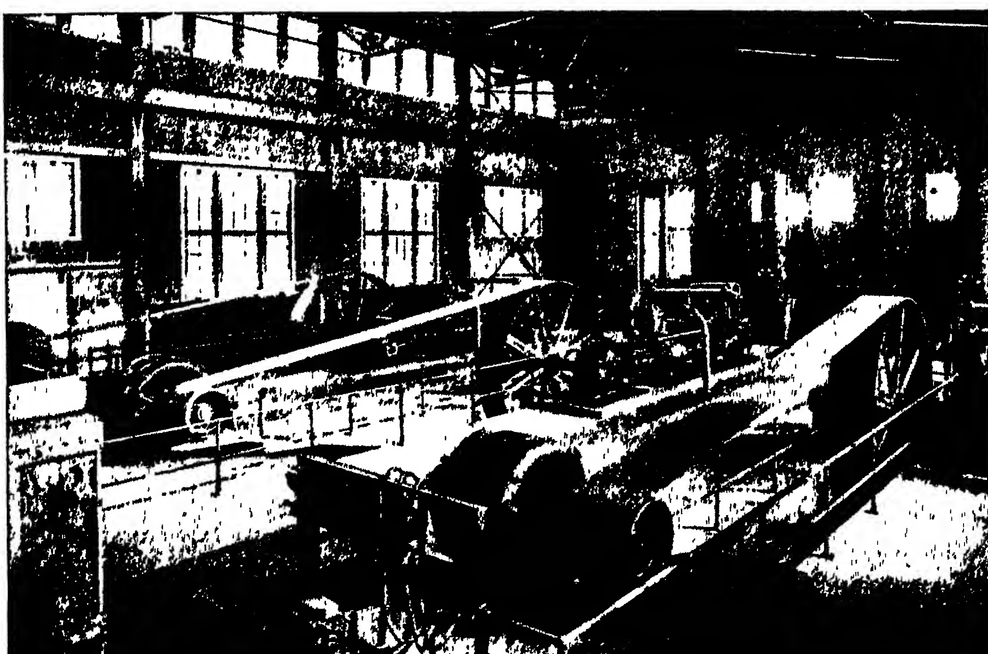
CARBIDE MILLS

The carbide is ground to a fine powder before introducing it into the cyanamide ovens. Mills of the same type are used for the grinding of the crude cyanamide.

NITROGEN BY THE CYANAMIDE PROCESS

CYANAMIDE OVENS (FIXATION ROOM)

The powdered carbide is placed in perforated cans set in brick-lined cylindrical ovens centrally heated Nitrogen from the liquid air plant combines with the powdered carbide to form crude cyanamide. The latter is ground to a fine powder and is used as such for the production of ammonia gas or is processed for direct use as a fertilizer.



Courtesy American Cyanamid Company

LIQUID AIR PLANT

Air is compressed and cooled until it liquefies and the nitrogen therein distilled in the three columns shown in the background of the picture. The pure nitrogen is pumped to the cyanamide oven room.

The salt that has given tenfold power to the worst human passions

Potassium, like sodium, occurs in large quantities in sea-water, principally as the chloride and sulphate; it is also contained as carbonate in the ashes of all plants, hence the name of "potash" is commonly applied to the carbonate. The most important commercial source of potassium, however, is the Stassfurt mines, in Saxony — an enormous deposit of sea-salts left there by the evaporation of a prehistoric ocean. Among the principal minerals containing potassium found in these mines are sylvine, or potassium chloride, the salt of potassium which corresponds to the chloride of sodium known as common salt.

Potassium is one of the elements of life, and neither animal nor vegetable life can subsist without it But one potassium salt, saltpeter, is notably a salt of death, since it is the basis of gunpowder Potassium carbonate is also much used in the manufacture of soft soap and glass. Potassium iodide and potassium bromide are well-known medicinal salts.

Interesting part that calcium has played in the biological history of the world

Hardly any element that the earth contains is of such geological and sociological interest as calcium. The pure element is difficult to isolate, and was for long unknown, but Sir Humphry Davy's discovery of potassium and sodium soon led to its capture; and within the last few decades new methods have been found of obtaining it, with the result that the metal has fallen in price from $500 to $3 per pound. Like sodium and potassium, it is far from a typical metal from a physical point of view: it is comparatively soft, it has little luster, and it readily tarnishes. As a pure metal it has no importance; it is its compounds that make it illustrious.

It is found in nature chiefly as carbonate of calcium, commonly known as chalk, limestone and marble, and this compound has played in various ways a most interesting part in the biological history of the world.

The chemical compound that has built up the higher animal life

Had the crust of the earth not contained sufficient lime to combine with a vast quantity of carbon dioxide as carbonate of calcium, the immense quantities of carbon dioxide at present locked up in the carbonate, which fizz out if we touch marble or chalk with vinegar, would have remained free in the atmosphere, with most momentous consequences to the climate of the earth, and to its animal and vegetable life A great amount, no doubt, would have been absorbed by the sea, but still there would have been quite enough left to modify profoundly both the climate and the biological history of the earth. An excess of carbon dioxide might have favored the growth of vegetation, and might have suited the lethargic reptilian life of the carboniferous period, but the higher mammals could not have thrived, and probably would have died in such a carbon-dioxide-laden atmosphere. To calcium, therefore, in a certain sense we owe higher animal life Not only so, but without calcium the structural complexities of plant and animal life could not have been evolved Calcium, in some form or other, is found in all plants and all animals; and the shells of the lower animals and the bones of the higher animals sufficiently attest its architectural value.

The quantity of calcium that has gone to make skeletons, that is indeed still making skeletons, is almost incredibly prodigious. Chiefly in the sea does it play this part, and chiefly in the case of shellfish and of those minute creatures known as "foraminifera" whose skeletons or shells go to form the deep-sea bottom. The deep sea is swarming with these little shelled organisms, and as they die they fall to the bottom and form a mud known as "the deep-sea ooze." Night and day, century after century, there is a hail of these shells falling through the sea, and the sea bottom is paved with these infinitesimal skeletons. How deep and to what extent they can accumulate, the land reveals, for much of it, as we know, was formerly at the bottom of the sea.

Chalk covers a great part of France, England, Denmark and central Europe, it is found in North Africa, in the Crimea and Syria, and extends as far as the Sea of Aral, in central Asia In the United States there is a broad chalk belt extending from Texas northward through Kansas to the Dakotas On chalk London is built, on chalk Paris is built. The white cliffs of Old England are chalk Lebanon is chalk, Ararat is chalk, Sinai is chalk. In chalk is written, so that he who runs may read, the story of the oceanic baptism of much of the dry land. Chalk tells us that at one time France, southeast England, Germany, Poland, Russia, Egypt, Arabia, Syria were all under the sea, and as in some places the chalk is more than a thousand feet thick, some bits at least must have been under the sea for many thousands of years.

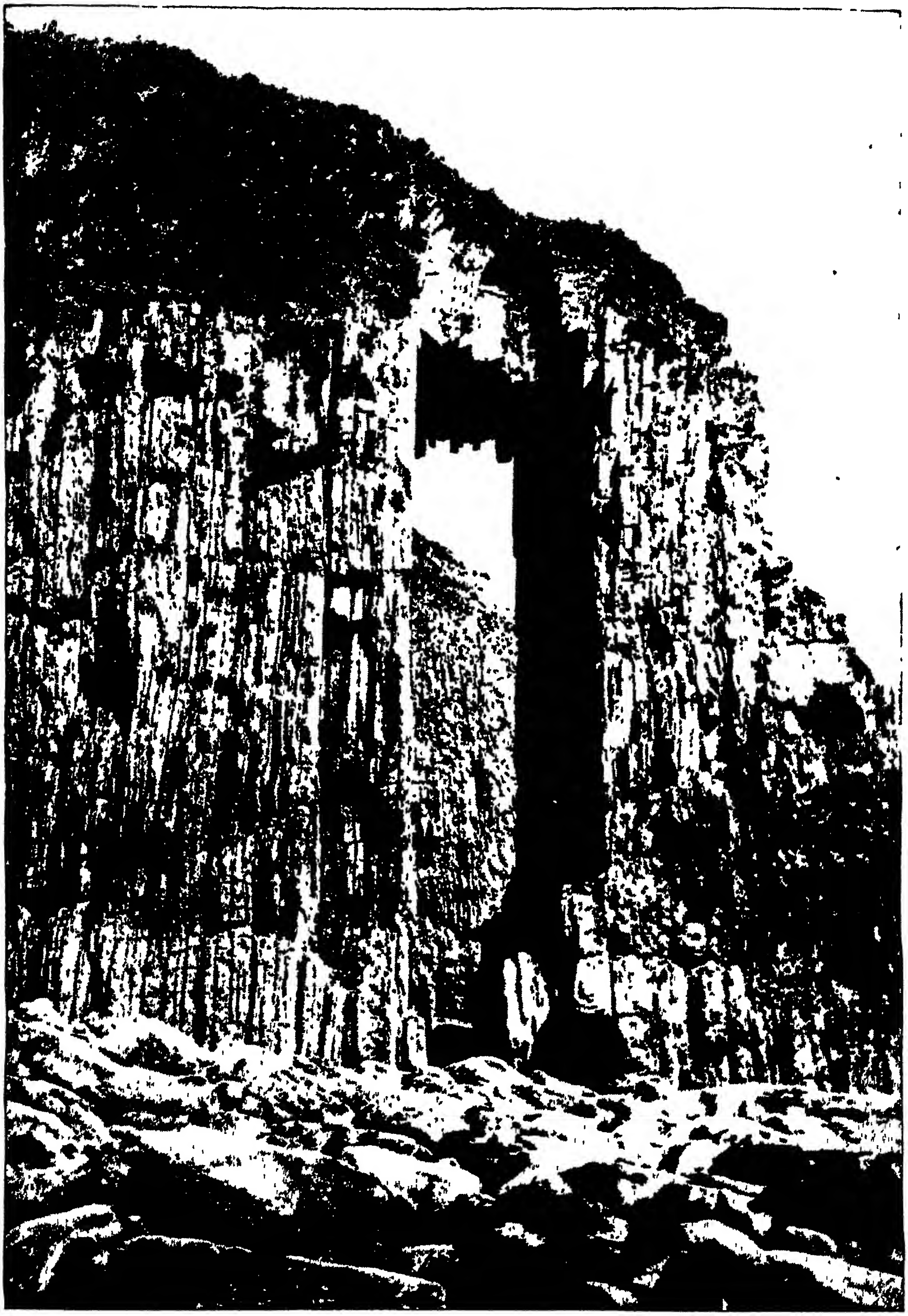
Chalk keeps for us, too, like flies in amber, the animals of the Cretaceous period, the last of the pterodactyls and ichthyosaurians, and plesiosaurians. Verily the chalk justifies its existence if only as a record on stone of the earth's history. Strange is it to think that man now uses the tiny skeletons of the chalk sometimes to cure his diseases, sometimes to clean his teeth, sometimes to whitewash his ceiling, sometimes to demonstrate a problem of Euclid. Strange that he should compound it with chlorine and use it to bleach his clothes. Stranger still that he should rub it on the tip of a cue in order to "English" a ball made of the tusk of an elephant, which is itself largely composed of calcium.

HOW LIMESTONE IS FORMED IN THE SEA

Many marine animals, such as are shown here, separate the carbonate of lime from the sea-water and form their hard shells, which, falling to the bottom, are transformed later into rocks

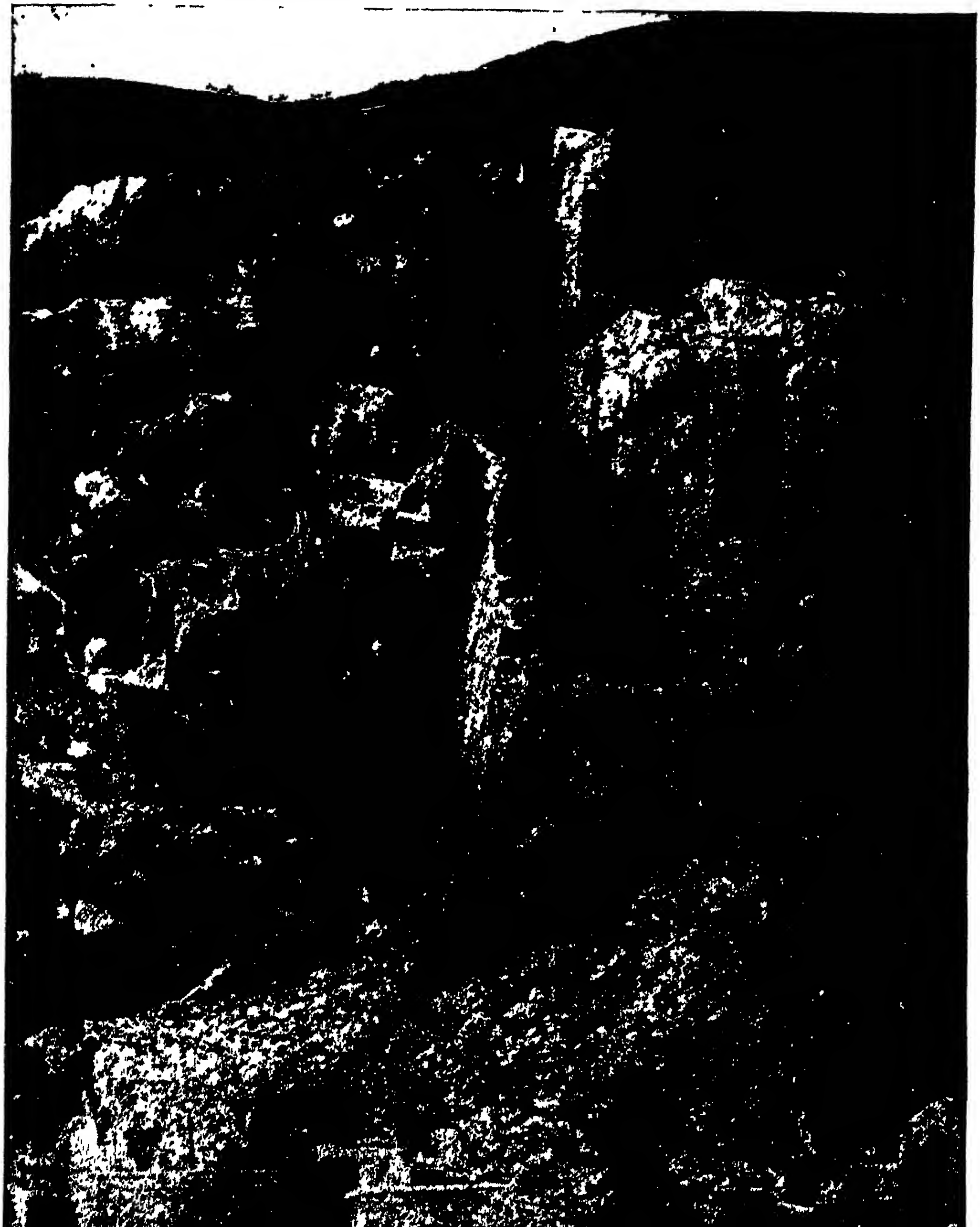
Besides chalk, there are other forms of firmer rock, as the nummulitic limestone, composed mainly of little shells of foraminifera of the genus nummulites, that peopled in prodigious numbers the seas of the Tertiary period. These shells were plastered over the bottom of that ancient sea that once covered a large part of Europe and Asia. In time the sea bottom was raised into dry land and mountain ranges, and formed this so-called "nummulitic" limestone, which is several thousand feet deep in some places, and extends through the Alps, Carpathians, Caucasus, Asia Minor, northern Africa, Persia, Baluchistan and the Suleiman Mountains, even to China and Japan.

Much of the rock made of carbonate of calcium has been transmuted, by contact with molten granite and by pressure, into the crystalline form known as marble, that substance wherewith man has realized his highest architectural dreams It was the Greeks who first exploited the marble mountains, but the Romans followed suit, and Rome became eventually a city of marble. "But as for the mountains," wrote Pliny, "Nature has made these for herself as a kind of bulwark for keeping together the bowels of the earth; as also for the purpose of curbing the violence of the rivers, of breaking the waves of the sea, and so, by opposing to them the very hardest of her materials, putting a check upon those elements which never are at rest. And yet we must hew down these mountains, forsooth, and carry them off, and this for no other reason than to gratify our luxurious inclinations; heights which in former days it was considered a miracle even to have crossed. Our forefathers regarded as a prodigy the passage of the Alps by Hannibal, and more recently by the Cimbri; but at the present day these very mountains are cut asunder to yield us a thousand different marbles, promontories are thrown open to the sea, and the face of Nature is being everywhere re-



This photograph represents the mass of vertical carboniferous limestone, known as the Horseback, on the English coast These rocks were formed ages ago at the bottom of the sea by the accumulation of shells and skeletons of many marine animals. The skeletons of all creatures are composed in great part of the same elements as these rocks, namely, carbonate of lime.

IN THE MARBLE MOUNTAINS AT CARRARA



This photograph of marble in its natural state was taken at the famous Carrara quarries, in Italy. There are many marble quarries in the Old World, as there are in the United States, but few, if any, of them can approach the best Carrara marble. It is of this white, pure marble, eagerly sought all over the world, that most of the great masterpieces of the sculptor's art have been chiseled.

duced to a level. We now carry away the barriers that were destined for the separation of one nation from another; we construct ships for the transport of our marbles, and amid the waves, the boisterous element of Nature, we convey the summits of the mountains to and fro."

Thus does Pliny describe the greed for marble in the Rome of his day. Everywhere were pillars, walls, baths, pavements of marble. It has been estimated that nearly half a million marble columns were landed at Ostia. Though the moralist may reprehend such ostentatious and extravagant marble magnificence, no one can deny that such marble buildings as the Taj Mahal, in India, and the Milan Cathedral are noble achievements; and when we remember that Pentelic marble was the material used mainly by Phidias and Praxiteles, that the Venus de Medici was carved in Parian marble, and that the finest works of Michelangelo were wrought in Carrara marble, we realize the debt of art to carbonate of calcium.

Marble formed of pure calcium carbonate is white. Mixed with iron oxides, it may be yellow, or pink, or red, and if it contain organic carbonaceous matter it may be blue-gray, gray or black. Some special kinds of marble have received special names. So-called "onyx" marble is a banded variety of marble, arranged in bands of white, brown and gray colors. The alabaster of the ancients was, as far as we know, what we call today onyx marble or Mexican onyx, and our modern alabaster is another calcium compound, the native translucent calcium sulphate. A very special kind of carbonate of calcium is the pearl which is secreted within the shells of various molluscs, the most valuable ones being those produced by the pearl-oysters and by the river mussels. Both of these owe their iridescence to the fact that the carbonate of calcium is gradually deposited in very fine concentric layers, like nearly all vitally formed lime salts intermingled with organic matter.

Another special form of carbonate of calcium is coral, the hard structure secreted by many animals living in the sea, as the corals, polyps, sea-anemones and others. In many cases, as is well known, coral accumulates so as to form coral islands and great reefs. The Great Barrier Reef of Australia stretches for 1200 miles along the east coast of Queensland. Many of the corals are very beautiful, and the red coral of the Mediterranean is specially prized on account of its fine color and susceptibility to a high polish.

Our bones and teeth are chiefly composed both of the phosphate and of the carbonate of calcium, so that calcium is their basis; and it is possible to write with a mammoth's decayed ivory as with chalk. Marble, chalk, coral, ivory, teeth, pearls, bones, all have calcium as their metallic basis.

Capacity of metals for ousting hydrogen of acids and substituting themselves

We can hardly speak of the alkali metals without mention of the acids, nor of acids without mention of the alkalis. All metals have a special capacity for neutralizing acids, by ousting their hydrogen, and taking its place, and we can define acids only as substances containing hydrogen which is ousted from its place in whole or in part by the metals with the formation of salts. Thus, nitric acid consists of hydrogen, nitrogen and oxygen; and if a little sodium hydroxide be put in it, the sodium immediately displaces the hydrogen, and joins the nitrogen and oxygen to form sodium nitrate. Again, sulphuric acid consists of hydrogen, oxygen and sulphur; and if a little sodium hydroxide be added to it, the sodium immediately displaces the hydrogen, and joins the nitrogen and oxygen to form sodium sulphate. It is a fact that all metals effect this substitution in acid, but the alkali metals are more soluble and effect substitution more quickly and readily. All acids turn certain blue vegetable dyes red, and all alkalis turn certain red vegetable dyes blue, and this is often used as a test of acids and alkalis.

The principal acids are sulphuric, hydrochloric and nitric acid; and the first plays such an important part in commercial chemistry that it is said that a country's prosperity may be estimated by its output of sulphuric acid.

CREATIVE EVOLUTION

How Life Climbs and Unfolds, but Most Swiftly Along the Open Road of Human Intelligence

THE STORY OF THE GREAT CONTROVERSY

FIRST as to names. "Organic evolution" is the correct modern term for that branch of the theory of universal evolution which deals with living beings or organisms. We might equally well speak of the development of one species from another; and years before modern ideas were made irresistible by the work of Darwin, Herbert Spencer was writing on the "development hypothesis." Later, he introduced the word "evolution" in its modern sense; and today we conveniently employ "development" for the history and changes of individuals, and "evolution" for the history and changes of races The theory of the transformation of one species into another is termed "transformism" by the French, but "evolution" is better.

"Darwinism" was long used as synonymous with the theory of organic evolution, because the Darwinian theory gained for it great acceptance; but the theory of organic evolution is vastly older than Darwin, and the term "Darwinism" is correctly employed only to indicate the particular theory advanced by Darwin to explain the process of organic evolution. Similarly, neo-Darwinism, a term in wide use today, is the theory that the special factor of evolution, discovered by Darwin, is all-sufficient; and it is opposed to neo-Lamarckism, the theory that the factors of evolution asserted by Lamarck are the essential ones. Each and all of these, together with Mendelism and Weismannism, are comprehended in, seek to contribute to, and assume the truth of organic evolution, but this theory is ages older than, and would survive, any of them.

In this department of universal evolution, as elsewhere, the old-new theory stands opposed, on the simplest or schoolboy level of thought, to the doctrine of special creation. We insert the qualification, not in order to suggest that the controversy is trivial, but merely lest we should seem to think it final and complete. It is a controversy essential to the truth, but it is not all. Our ancestors believed that mankind and the other forms of life, animal and vegetable, had been specially created by Deity, as described in the Book of Genesis The Biblical account of the Deluge also consorted with this idea; and strange remnants of forms of life now extinct could thus be labeled ante-diluvian. The evidence of geology, with its records of strata and their characteristic fossils, required explanation; and the geologists were apparently equal to the task.

They said that other forms of life than any now known had existed, but great cataclysms of nature had terminated them, perhaps leaving records of one kind or another behind; and that, in the new era which succeeded, new forms of life had been specially created, and so on, many times. To all this, we of today oppose a theory of organic evolution which holds that none of the forms of life, either extant or extinct, of which we today have any knowledge, were specially created, but that all have been derived from preëxisting forms. As has been pointed out in a previous chapter, the theory of organic evolution accepts as a fact the existence of living things in the dim past without presuming to say what was their origin. It maintains that later

and more highly specialized forms developed or "evolved" from the simpler forms that preceded them and it seeks to discover the lines of this development and the laws that brought it about.

The theory of organic evolution involves origin of man and so shook the world

Remembering that we have not yet plumbed the depths, and that very few even recognized champions either of religion or of science ever do, we may realize why the controversy between this and the older view shook the world to its base, and why, after its conclusion, we live today in a new world of thought. The controversy involves the origin of man, and the question of his relation to the lower animals. Darwin avoided this aspect of the question in his thunderbolt of 1859, but there were plenty to see that it was involved. Elsewhere in this work the evidence has been outlined which points out the resemblance in structure of the body of man to that of the anthropoid or manlike apes, and to the possibility of a common ancestry in the far-distant past. No one could assent to the theory of organic evolution in general, and leave out man The utmost possible, in the way of a distinction, was made by Dr. Alfred Russel Wallace, who argued that the spirit of man could trace no genesis from lower forms, and must be a product of special creation, though the animal origin of his body is beyond doubt.

The battle of thought in which there could be no compromise

But even so, and even though man be left out of the question, the theory of organic evolution seemed to be incompatible with the assertions of certain ancient literature, the verbal inspiration of which was generally believed in. The question whether or not organic evolution had happened, which is a scientific question, and which no one would dream of treating otherwise today, thus came to be, fifty years ago, a question of religion *versus* science. Religion was taken to make one assertion, by which it stood or fell, and science specifically denied it.

Religion declared definitely that man had been created perfect and had fallen; while science declared that man had risen from an animal stock On the literal, obvious, schoolboy plane, there could be no compromise. The disputants, with very rare exceptions, wanted none: and the controversy, in the hands of most of them, and in the eyes of the general public, came to be a veritable battlefield, with God and religion at stake against atheism and irreligion.

To this view of it the fighters lent color, by misunderstandings and misrepresentations, which we can now begin to see aright, if we will. The champions of religion fought hard and bitterly, declaring that religion was at stake, as if any kind of truth could ever compromise or do anything but strengthen any other truth. If organic evolution has happened, man has not fallen, but risen, and the Creation story in Genesis is not to be taken in its literal significance. Certainly, there were serious and inevitable changes to make in the accepted interpretation. But the religious party went further, and declared that to accept evolution was to deny God; that evolution is materialism, excludes immortality, makes chance the master of all things, and right, wrong and duty mere meaningless words.

Of course, there were exceptions on both sides, but on the whole there was little to choose between them, if we put aside the few really great men. For the scientific party was just as violent and extreme The champions of orthodoxy should not have been intellectually bullied into arguing that evolution denied God, but certainly the scientific party did their best to create that impression. What we really mean by God, and what we really mean by creation — these are questions which are not asked by schoolboys, and they were not asked by the rank and file in this controversy. The evolutionists erected their word into an idol and then bowed down before it. They declared it to mean chance, with such laws as chance has, but without purpose; and they took evolution to be a cause, instead of the mode of working of a cause.

Threefold advantages we possess in considering the theory of evolution today

Their opponents, eagerly fighting for the Fall of Man and the literal accuracy of the Book of Genesis, could not afford to yield anything, or they might well have accepted evolution as the statement of a *process* — which is all that it was and is — and might then have pointed out that the cause and the force manifested in the evolutionary process had still to be named and cannot be less than Divine

We come to this question now, more than half a century after Darwin published the "Origin of Species," which started the controversy; and we are able to criticize our predecessors, because we have great advantages — advantages so great that it is our own fault if we cannot survey the matter today, and pierce below the thin, smooth ice upon which most minds skate, till we realize the fathomless depths beneath. Our advantages are at least threefold.

In the first place, the controversy, on its plane, has been settled once and for all, before our time. Every sincere person who has given thorough study and thought to the subject has become convinced that organic evolution has happened. If that fact involves the rejection of certain things formerly believed, or if, at least, it involves their rejection as literally true, then rejected they must be, "and there's an end on't."

We may regret them, but we have no choice. The battle being ended, and its passions cooled, we may now quietly examine the results of the controversy — the almost universal acceptance of the theory of evolution. And to this business all parties now contribute, *for, once evolution has been accepted, its real meaning becomes the concern of religion as much as of science.*

Secondly, the few deep voices on the religious side have been added to as the years have passed; and while the shallow ones are lost in the echoes of the years, these remain, and teach us that perhaps religion was at fault in lacking faith, and in having too petty an idea of God.

They point out, as indeed did Darwin himself in the final sentence of the "Origin of Species," that the theory of evolution does not dispose of God, but glorifies Him by attributing to Him a grandeur and scope of method compared with which "special creation" is like the caprice of a child. Further, the professed representatives of religion are joined by those of philosophy, which occupies, so to say, a middle position between science and religion. The philosophers, deep and trained thinkers, who are always necessary to correct and amplify the conclusions of men of science as to what they find, point out that the evolutionary process is only what we see on the visible side of things, and that things are but the "living garment of God." They have lately been reinforced by a great new thinker whose views we must look at.

The theory of evolution much more cautious and limited in statement today

Meanwhile let us note the third of our advantages today. It is that men of science have studied and criticized and modified the evolutionary theory to great profit, both in the way of what they now assert and of what they no longer assert. We must remember that, at first, people like Huxley had to fight for the smallest acknowledgment at all of what science found.

We are prone to call Huxley polemical and arrogant today, forgetting what measureless ignorance and arrogance and misrepresentation he had to fight against. May the next great new truth find another such champion! Born in our age, Huxley would have no occasion to fight as he did; the controversy is over, the religious world has accepted the idea of evolution, and now men of science need claim no more for it than they are assured of, and may criticize and make admissions without the certainty that those admissions will be misrepresented and used against the theory as a whole. The consequence is that the theory, as it may justly be stated by science today, is in some ways much more cautious and limited than the older statements of it.

A VALIANT CHAMPION OF EVOLUTION

PROFESSOR HUXLEY, FROM THE PAINTING BY THE HON. JOHN COLLIER, NOW IN THE NATIONAL PORTRAIT GALLERY, LONDON

This is where Bergson helps us. Since Herbert Spencer himself, to whom he is greatly indebted, Bergson is the first philosopher of high rank to appreciate the importance of biology Plenty of philosophers and theologians have pronounced upon the problems of life, in the interval, but they have not studied them first. Bergson has done better. He has devoted many years to the systematic study of biology, not stopping with Spencer and Darwin and the other pioneers, but continuing with the work of their successors, and acquainting himself with all the new laboratory work, much of which dates from the last few years. No other professed philosopher of the present day has any such acquaintance with biology, for none since Spencer has realized that, before we can pronounce upon the problem of life and its meaning, we must first acquaint ourselves with its facts—nay, not merely with the facts already known, but with countless more. Bergson occupies the middle position of the philosopher, and also the advantageous position of the man of today. The fighting and bad temper and over-statement of the past do not rankle in his mind, and he is not concerned to see science triumph over religion, or religion over science.

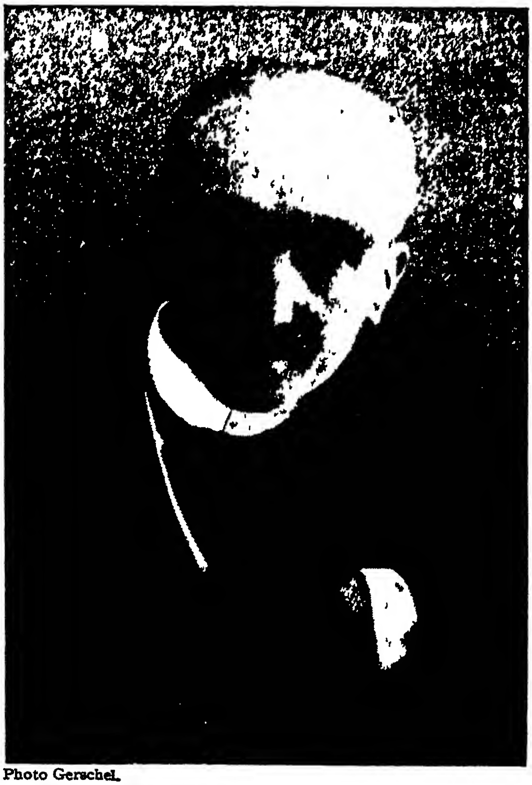


Photo Gerschel.
HENRI BERGSON, THE PHILOSOPHER OF CREATIVE EVOLUTION

Creation *or* evolution was our simple alternative. Bergson's greatest work, the fruit of his biological study and his philosophic thought, is called "Creative Evolution." Where is our antithesis now? The book is very long and difficult. Few will read it easily yet; most will complain, as men complained of the "Origin of Species," that it was hard and obscure reading, though now we find it easy and clear. But the modern writer on biology, who strives to introduce, with absolutely impartial and scientific temper, the problem of organic evolution as it really exists and is understood today, neglects a duty if he does not take cognizance of this great book, which quite clearly takes us a step beyond the nineteenth century and its controversies, and builds something higher upon its solid contributions to knowledge.

Bergson recognizes the fact of organic evolution, studies its processes, and asks what it means. To begin with, he sees that Life is different in its trend from the rest of the universe; for while the evolution of other things is always in the line of least resistance, and always resembles a running-down, as the physicists express by their doctrine of the dissipation of energy, life takes the line of most resistance, life climbs while matter descends. In other words, it constructs and creates. Behind the mechanical forces of the world there is life, which uses them for its expression, but which can never be expressed, or explained away, in terms of them. The mechanical theory of Darwin, which explains the origin of species by the process of "natural selection" or the "survival of the fittest," does not escape Bergson's philosophic criticism. We shall see in due course how it stands in the face of scientific criticism.

Meanwhile we have to observe that, philosophically, the evolution of life cannot be adequately stated in terms of any mechanical process

Unlike most men of science, to say nothing of amateur commentators, Bergson really understands what the Darwinian theory of evolution is, as we see from his words· "The Darwinian idea of adaptation by automatic elimination of the unadapted is a simple and clear idea" This admirable statement, in which the word "unadapted" expresses the theory exactly, neither more nor less, expresses also the fact, that the theory *tells us only why the unadapted disappear*, but *does not tell us how the adapted appear* —which is the *crux* of the whole question.

But, being a philosopher, Bergson is bound to look closely at the meanings of words, and he is not content to take "adaptation" so easily for granted. When we speak of the adapted or the "fittest," we are using a convenient and illuminating metaphor. If we pour water into a glass, it adapts itself to, or fits, or repeats the form of the glass. That is mechanical adjustment. Similarly, a key may be made to fit and turn a lock; and thus, in metaphor, we may think of any living species as a key which turns, because it fits, the lock of its environment — to use an illustration employed by the present writer some years ago. All this is useful, so far, and especially useful against the misinterpretation which confounds the survival of the fittest with the survival of the best — as we shall see when we come to study Darwinism. But Bergson points out, to those who would reduce evolution to a mechanical problem, like a locksmith's, that we must not be "fooled by a metaphor."


FOSSILIZED PLANTS — PART OF THE STEM OF A GIGANTIC CLUB-MOSS

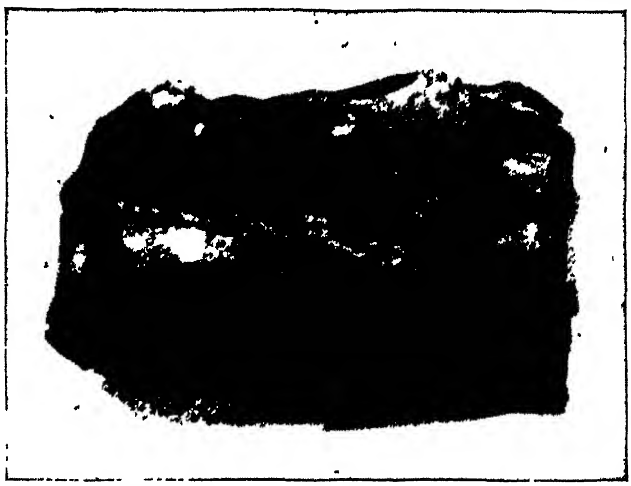
Life is not poured into a mold, made by the circumstances. "It will have to make the best of these circumstances, neutralize their inconveniences, and utilize their advantages — in short, respond to outer actions by building up a machine which has no resemblance to them. Such adapting is not *repeating*, but *replying* — an entirely different thing" Adaptation, the great fact and consequence of evolution, which any theory of it must explain, is not the "impress of circumstances, passively received by an indifferent matter," but is "an effort of the organism to build up a machine capable of turning external circumstances to the best possible account."

This means that evolution is creative. It supports Bergson's idea of a "vital impetus," or "*élan vital*," to use his own term, which various translators have called the "momentum," the "thrust," the "impetus," the "go" of life. This, as we have seen, opposes and transcends the mechanical movement of matter, and cannot be comprised within the terms of mechanism. It is transmitted from generation to generation, and expresses itself in all the forms of life, some along roads which lead no farther, but one, which we call human and intelligent, along an open road. Here is creation, displayed in the form of evolution; and the materialism of the nineteenth century is dispelled, and replaced by a deeper view, which sees that creation is not "special" because it is universal and eternal. Would either Darwin or Bergson disagree with such a conclusion?

Having thus considered the larger aspects of our great subject, aspects which do not concern the ordinary levels of science, we may pass on to our own proper topic, simpler, if less momentous.

The facts on which the theory of organic evolution is based are beyond question and, as a matter of fact, are no longer disputed by anyone who is at all well informed. We may now look at the main lines of evidence to which science points in support of this theory. It consorts with everything else we know — the history of rocks, stars, atoms. That is a statement which no one could make half a century ago, when the facts of universal evolution were unknown.

Most serious for Darwin, and for all evolutionists until very recent times, was the geological objection to which, in his chapter, he gives full weight. It is that the records of the rocks do not afford intermediate varieties between species, such as we should expect, if they had been evolved from one another by slow and insensible degrees. If that had been the process, then the rocks should show us some traces, at least, of transitional forms, corresponding to intermediate stages between this and that species, now extant. Darwin definitely argued that evolution is a gradual process, that nature does nothing by sudden jumps, and that species have arisen by the steady accumulation of minute differences. On that view, the "imperfection of the geological record" was a great difficulty. But it is not so difficult for us. Professors Hugo de Vries of Amsterdam and William Bateson of Cambridge have shown us how new forms may arise suddenly, nature's alleged dislike of jumps notwithstanding.



FOSSILIZED ANIMALS — FLIES PRESERVED IN AMBER COUNTLESS YEARS AGO

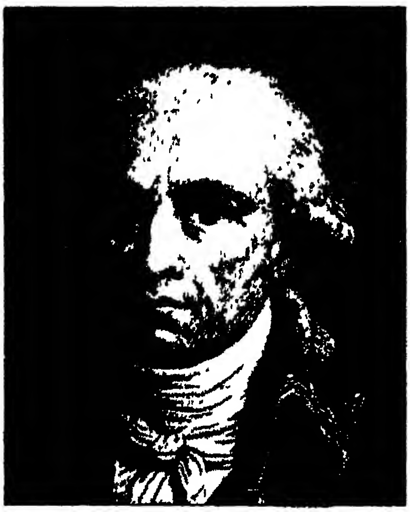
In our day the study of the development of the individual has greatly strengthened the case for evolution. This study, in the case of the higher animals, is called embryology, being so largely concerned with the examination of their early or embryonic stages. As we have already seen, the facts of development, when we compare them in widely various species, are unintelligible unless we try to interpret them on the assumption that evolution has happened. If, however, we apply the law of recapitulation to the problem, we see how the strange and often apparently absurd details of individual development find an explanation. The young creature is climbing its own ancestral tree. If we assume, for instance, a fish-like form in the ancestry of man, many facts of the human embryo become intelligible at once which otherwise look as if nature had gone mad.

So also the study of the anthropoid apes and of man reveals a similarity at certain early stages that can be explained only by the assumption that they are divergent lines developed from a common but far-distant ancestry.

In our own day, also, as regards the tremendous case of man, we have further evidence, such as the discovery of the "ape-man," the similarity in the body structure of man and the anthropoid apes, and their similar susceptibility to certain diseases.

A great and general difficulty has to be named, which at one time seemed insuperable, or nearly so. Indeed, Huxley always maintained that he could not regard the theory of organic evolution as proved so long as species remained incapable of mating with each other to form new species.

There are many cases where different species of animals can mate, producing such offspring as, for instance, the mule. These products of two species we call "hybrids," and it appeared to be a constant rule that hybrids are sterile. If that were so, evidently the possibilities of the formation of new species were seriously limited, but the sterility of hybrids seemed to be nature's rule It must be remembered that experimental breeding, either of animals or plants, by men of science, and for the purposes of knowledge, was a very rare affair until the present century.



JEAN BAPTISTE LAMARCK, THE GREAT FRENCH NATURALIST

Barriers that disappear in the light of new knowledge

Biologists had to go by the opinions of breeders, such as Darwin himself frequently quotes. He, however, performed breeding experiments, and Mendel did so too, though no one knew about it; and later De Vries and Bateson and many others have taken to experimental breeding on a large scale, most notably in the United States.

The study of hybridization, which used to be looked upon as a curiosity, and of no general moment, has been placed on an entirely new level by the work of Mendel and his followers; and one of the most important of the results they have obtained is that hybrids are by no means necessarily sterile, and, even when they are, the sterility may only be due to accidental circumstances of structure, and not to any inherent disability of the hybrid to reproduce itself. Indeed, many hybrid forms can be bred and found to breed true, so that new races can be developed.

What this means for the theory of evolution is our only present concern, but it is a great one. It means that the supposed barriers between species, like the other barriers which men erect in nature, disappear on further knowledge. Our idea of a species as an immutable thing, self-contained and separate forever, cannot be maintained when we see how species are really constituted, when we learn the results of hybridization, and when we begin to think of all individuals as living mosaics, from or to which certain constituents may be taken or added, or substitutions made, in any degree, until one species becomes another.

In any particular case this may not be feasible, but in many it is, and the lesson is plain. Huxley's notable and long-maintained criticism is thus met; and we are able to look at the theory of evolution with ideas of what constitutes a species, and of the relations between species, which make it seem far easier to understand.

For many future chapters of this section, and for many decades to come, we shall be concerned with the factors of evolution, and with weighing the factors which we must admit, and seeking to interpret the multiform problem before us. Let us be as clear as words can make us: that science has accepted the theory of organic evolution, that to doubt it is to show a lack of proper information, and that it is a theory worthy to be known and appreciated by all thoughtful people. And then let us be equally clear that science cannot yet explain all that stands in need of explanation, that we cannot even attach anything like the same weight to certain explanations as we used to suppose, and must do much hard work, above all by means of experimental breeding of animals and plants, before we can offer an explanation to complement our description.

Similarly, in another branch of science, the authorities teach us that gravitation is a universal fact, which they rightly assert with absolute dogmatism, but if they are asked to explain gravitation they can only say they do not know We know much more towards the explanation of organic evolution than astronomers know of gravitation, but we have the greater part yet to learn.

One serious and urgent question must here be raised in conclusion. The modern attitude towards the particular theory of its explanation called Darwinism is not the same as Huxley's and we see that there is yet more to learn, but the theory stands, and will stand. This being so, are we any longer entitled to usher children and young people into the world of modern thought by teaching them the doctrine of "special creation," or has the time come when we ought to teach what we believe? The man of science can give only one answer to this question; and the practical moralist has plenty of facts already with which to guide his decision. Our young people will certainly grow up to learn that the theory of organic evolution, including that of man, is recognized and accepted as the truth. It cannot be kept from them, nor they from it. If we do not teach them, others will. A recent book on the study of nature, written for and used in the most illustrious school in England, carefully speaks throughout as if the theory of evolution had never been heard of. The only result of such a policy is that our young people learn the facts for themselves during the critical and deeply impressionable age of adolescence, and learn them from sources which are less concerned with presenting the facts fairly than with using them as weapons against religion. The "Origin of Species" would once have been publicly burned by the common hangman; but the noble book can morally harm no one, though it has distressed many. But our youth are as likely to learn the facts from violently materialistic books, belonging to an era of thought now obsolete, such as Haeckel's "Riddle of the Universe," and works of that kind.

The powers in the Church and educational world, right up to the university stage of education, who ignore their duty in this matter, or who positively base religion and duty and morality upon doctrines which are incompatible with evolution, are responsible for the grave consequences.

This doctrine is in accordance with known facts, it is important, and it is intelligible — perfectly so to any boy or girl of twelve or fourteen. If those assertions be granted, what possible excuse can there be for not merely ignoring it, but for teaching the views which discredit the theory of evolution and which in the end are certain to be discarded? Something must be taught, as, for instance, regarding the origin of man. Shall we teach that the body of man was fashioned once for all just as we find it today, or shall we teach that mankind has been developed from some lower form of life under the guidance of that Power that governs the development of all living things? The child whose confidence has been abused will grow up and find us out. In some instances suddenly and consciously, and perhaps with measureless distress of soul, in other instances gradually and only half consciously, he will cease to believe what he has been taught by those whom he should be able to trust. He will throw away the dross, but with it he will also throw away some gold.

Yet may it not be that the necessary teaching of our young people is easier if we look at organic evolution in the light of the foregoing pages, and carefully distinguish between the indisputable, descriptive fact, the problem of its explanation, and the grandeur of its meaning? It may be hoped that the time is nearer, in consequence of these arguments, when those responsible will see the doctrine of organic evolution as it is, not as violent controversialists on both sides misrepresented it a generation ago; and then we may begin to discover that morality can be better based upon the "solid ground of nature," even though the waters to dive through be black and deep, than upon the thin ice to which the frail of faith have trusted hitherto.

NATURE'S RESTING-HOUR IN AUTUMN

These pictures give us the feeling of autumn's refreshing pause, when the earth is quietly collecting her life-producing energies in anticipation of a fresh outburst under the returning sun.

AUTUMN'S STORAGE OF LIFE

Mistakes Made about the Season when Nature Cheerfully Consolidates her Reserves of Strength

THE SECOND SPRINGTIME OF THE YEAR

ALMOST all people regard autumn as a time of decay, if not of melancholy. They see the leaves losing their fresh green and as this green, or chlorophyll, disappears, shades of yellow and red and russet take its place, until, as it seems, the leaves are too weak and lifeless to hold any longer on the twigs. They fall and the trees become "bare ruined choirs where late the sweet birds sang."

In autumn the days grow shorter, the mists cover the low places in the mornings, many of the birds have ceased to sing, and many more are flying away to the south Surely autumn is a time when the world about us is losing its vitality.

In some countries this is so. It is so in the North. Even, for example, in Newfoundland, which has a beautiful climate in autumn, the birds disappear, and none arrive, and the farmers begin to cease work in the fields. In Canada less wheat is sown in the autumn. If seeds were sown then, the majority of them would be killed by the weather of the following months or, rather, seeds that lay dormant and did not sprout would perish, and those that grew would produce plants that would have little chance of living through the cold winter.

In countries with mild climates, such as England or the cotton belt of the United States, seeds sown in the autumn germinate well and quickly, and produce, on the whole, better plants than the grain sown in the spring. Winter oats — oats sown before the spring comes — as a rule yield a larger crop and resist disease and drought very much better than grain sown in the spring.

Many florists always prefer to sow such annual plants as sweet peas in the autumn rather than in the spring, though the difference between the two is not very highly marked. The reason is that the plants have made good roots before the excessively bad weather comes; and by springtime, though they have not grown a great height, they are ready to share at once in the new warmth and the longer hours of light and nature before the excessive heat of summer. The various diseases do not find them such susceptible victims.

The truth about most autumn- and spring-sown grain is that, in a great majority of cases, the autumn-sown is much the better. But if spring and early summer are all that they should be in respect of continued heat and moisture, the difference is not great; and if the autumn happens to be very wet, or the winter exceptionally hard, the spring crops do the better.

But, apart from the comparison of the two from the point of view of the farmer, it is clear that autumn is in many ways a sort of spring. Like spring, it is also a seed time. Of course, almost all the common plants, notably the annual weeds, such as dandelion or milkweed, sow themselves of necessity in autumn. Some of these seeds come up at once, some lie dormant. In favorable years one may see fields as thickly covered with small seed-leaves as if they had been sown on purpose. They can easily be destroyed; indeed, very many will be killed by the weather, and will do no little good to the land. They will restore to the earth the nitrogen without which few plants can flourish.

In looking, then, at the "happy autumn fields" — many of them green with the waving blades of oats and wheat, among which are flocks of birds that have just arrived — we have to think of the season as a time of growth and vigor. But it is not only in the seeds and on the fields that this vigor is apparent. It is hardly less apparent to the eye of the scientific observer in the trees and upon some of those plants which have seemed especially to express with their withered leaves the melancholy period of decay.

It is not quite true to say that the leaves decay and fall. Sometimes, no doubt, when a hard frost comes before its time the leaves of some trees, especially the ash-trees and chestnuts, are shriveled up and killed and so fall prematurely before their time. But generally, and in regard to most trees, this is not so. The facts are that, in the first place, the tree throws off the leaves with a vital and vigorous action which it is most interesting to watch and observe closely, and, secondly, that the leaf which seems to be simply withering away for want of vitality is also engaged in a busy work which may be compared with that of the squirrel who is storing nuts in his winter nest high up in the tree or in a hole in the ground at its foot.

SHOOTS OF HORSE-CHESTNUT IN AUTUMN, SHOWING HORSESHOE MARKINGS AND STICKY CEMENT WITH WHICH THE BUD IS CLOSED AGAINST ANY POSSIBLE ATTACK FROM INSECTS OR WEATHER

What is the green in the leaf, and what purpose did the leaf serve in growing and becoming green? The leaf is a part of the machinery of the tree and, after the roots, by far the most important part of the machinery. It is designed to help in adding vigor to the whole. Throughout the whole of the spring and the summer it was engaged in manufacturing life-blood for the use of the tree. But it has a further task. In autumn it is engaged in passing the stores that it has manufactured into the reservoirs. The chlorophyll — or green-stuff, or life-blood — is quite literally poured back from the leaf into the tree. With the help of a microscope, and by careful inspection of the build and structure of the leaf and twig, we can see the pipes, as it were, along which the fluid is sent. What we cannot see, what no eye has ever yet seen, is the force which does the work and prompts the leaf in this particular case to send the stuff of life back into the tree. But, though we do not know the original force, we know the fact. We know the stuff goes back, and this ebbing or flowing back of the tide of life is a work, not of decay, but of vigor. It needs and calls forth energy. Outwardly, most of us will not notice the result of this energy till next spring, till the tree, fed with this new supply of energy, begins to put forth again more leaves that are to make yet further supplies.

But, without using a microscope, anyone can see growth going on up till quite a late period in the year. In the axil, or angle, between the leaf and the twig, the next year's bud has been nestling, perhaps two or even three buds, one inside the other. These buds go on forming and swelling during a considerable part of the year; and they are fed to some extent by the chlorophyll passed back by the so-called "dying" leaf. There is no time of the year when we can say definitely that these

buds are formed Some are leaf-, some fruit-buds A fruit-grower can tell early in their life which buds on his trees will bear flowers and which leaves, the flower-buds being fatter, stouter and less pointed than the others But now we are speaking of leaf-buds. Whenever the bud takes its true form, it is certain that autumn is a very important season, and it is popularly believed among fruit-growers that the show of blossom in the coming year depends most on what may have been the weather of the preceding autumn

It is an interesting study to watch these buds and reserve buds, to see when they appear, and swell, and cease to swell Not the least interesting part of them is the way they are cased in and hermetically sealed against the attacks of insects or weather. The buds are particularly interesting on the ash, bearing a certain resemblance to a deer's foot. They become at one period pitch-black, and no tree has a greater tendency to grow a succession of reserve buds But they are perhaps easiest to observe on the horse-chestnut, which in a variety of ways is a delightful student's tree. The buds are very big and conspicuous. With a sharp knife we can so cut the bud as to see all the parts of the coming flower-spray months before its time for opening. The tree secretes a sticky cement with which it closes the bud against possible attack.

ENLARGED SECTION OF TINY BUD ABOVE RIGHT-HAND HORSESHOE MARK IN THE OPPOSITE PICTURE

If we examine any chestnut twig — and the marks are especially noticeable in autumn — we shall see at various distances along it successive patterns which resemble a little a horseshoe very much opened. There is a rough crescent of smooth bark, and upon it a line of slightly raised lumps suggestive of small nail-heads. The marks are so curious and evident that they have been used by scouts, who have written their own signs on the twigs, and the writing has entirely escaped notice because of the number of natural marks found on each side of it, and on neighboring twigs.

This mark on the chestnut is a sign, blazoned on the bark, attesting another of the vigorous actions of the autumn season, which the world calls a season of decay. The horseshoe is the mark left by the fallen leaf, but it did not fall by its own want of vigor so much as by the active effort of the tree to get rid of it. In nearly all trees, when the leaf has finished its work, there grows between the leaf and the twig from which it sprang little layers of cork or corky substance. In the different varieties of trees these little corky lumps take different patterns, and an expert forester could tell us the name and variety of most trees in mid-winter solely from these patterns.

In any course of nature study, or in the natural course of observation, a collection should be made of these various markings, all of which fall into patterns as simple and as distinct as are the shapes of crystals in different forms. As each form has its distinct crystal, so each variety of tree has its proper leaf-pattern; and the pattern indicates the active effort made by the tree to expel the old leaf.

We can easily tell that there is an active effort by noticing the contrast with a dead or half-dead bough.

Partly break any twig so that it still hangs on the tree but does not any longer share in the flowing of sap What happens? The leaves wither quickly. They do not go through the slow, natural process, nor do they gradually, or indeed at all, take on the various autumn colors of yellow and red of the neighboring leaves. Instead they wither into browns and blacks, and hang where they withered. Their torn and withered shapes will remain on the broken twig long after the other leaves have turned color and fallen. This means that the dead or dying twig had not enough vital energy left to thrust off the old leaf, as did the living twig which felt the energy of autumn.

Of course all trees do not behave in the same manner. Oaks will often keep on many of their brown, withered leaves right through the winter, and they will not fall till the new leaves begin to swell in late spring. Beech trees also have a tendency to keep their red-brown leaves, and horn-beams, distinguished from beeches by the dull brown of their old leaves, do much the same So-called "evergreens" throw off their leaves for the most part in spring, and there is no easily traceable back-flow in autumn In countries such as Australia, where there are no deciduous trees — that is, trees which lose all their leaves every year — the vigor of autumn is much less real and very much less perceptible than in the north. On the other hand, of course, there is not the same appearance of decay, as the leaves keep their greenness throughout the entire winter.

AUTUMN IN THE WOODS, SHOWING THE RICH CARPET OF FERTILIZING LEAVES

Again, annual plants do not behave in this way. Generally speaking, plants are divided into the three classes of annual, biennial, and perennial. The annual plants, whose roots do not survive after their one season, put their chief vigor into making seed to insure the growth of new plants in the following year. Many of them will go on wrestling up to late in the year to produce seed if the first efforts fail. Sweet peas, for example, will flower into October if no seed is allowed to set earlier, and the common weeds will persist

in throwing up flower-heads if we prevent the first flowers from coming to seed It would be of no service to these plants to feed the roots with the riches they have stored. Grain of all sorts, it will be noticed, ripens upwards, as farmers say; that is, the straw hardens and loses its greenness and its sappy nature first at the bottom, and finally close to the ear.

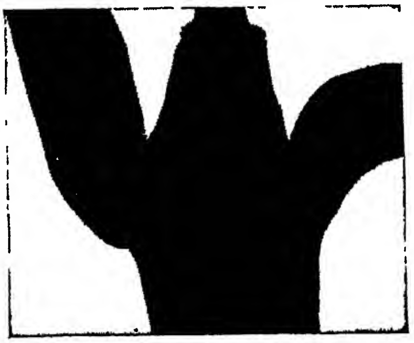
Biennials, on the other hand, spend their first year in building up strength in the root in order to flower well in the following year or years for, though they are called "biennials," such plants often last more than two years. The garden carrot is a good example of this division. What we eat is the food-supply laid up by the plant for use in the following year. This we take, in our masterful way, and turn to our own use before it can be turned to its natural use.

The chief part played by the leaves is to send stores of food to the bulbous root. In perennials, plants which live on indefinitely from year to year, the vigor of the plant is always lessened if we cut off the leaves before they have parted with their juices. Almost every gardener knows this truth in respect to his bulbs.

The tops of crocuses, daffodils and snowdrops, however untidy they may look, are not cut off till they are withered; and the reason of this is that the leaves are feeding the bulbs. Indeed, in many bulbs, notably the crocus, the leaves grow to a great length after the plant has done flowering in order to absorb more food for the bulb. As we can increase the vigor of plants by letting the leaves wither and part with their fuel, so we can quite easily destroy plants by cutting off the leaves. Even that persistent thing a plantain can be made to perish by successive cutting of the leaves. Beds of nettles will not survive the frequent use of the scythe. The most ineradicable of all weeds is the convolvulus, or bindweed. Each tiny bit of white root has the power of sprouting and producing great tendrils. But convolvulus is as surely killed as any other green-leaved plant by plucking the leaves before they begin to languish.

EARLY SPRING BY THE LAKE, SHOWING LEAVES THAT A BRANCH HAS LACKED ENERGY TO THROW OFF

Autumn is a season of "mellow fruitfulness" in many ways, some of which are little noticed. We all notice the scattering of seed. The luscious stuff round the seeds of an apple persuades the bird to help the fruitful part to be carried away or made fit for germinating, and the thistledown is wafted by its wings and by the wind many miles away to start another plant. But a more conspicuous example of the energy of autumn is to be seen in such plants as the blackberry. In the autumn months the long shoots bend down till, at the end of the fine curve, they touch the ground. If the soil is at all congenial, or if the top is in any way pulled down into it, the leaf-shoots begin to turn into roots, and when spring comes it will be found that a completely new plant is produced. The blackberry has "layered" itself naturally. This layering has become a much more general garden and horticultural process of recent years since other berries have been "created" by scientific gardeners.



THE DARK LINES SHOW THE GROWTH THAT FORCES THE LEAF TO FALL

There have been added quite a number of plants, such as the loganberry, all descended from the blackberry and the raspberry, which layer themselves easily and well. They can be multiplied either exactly in nature's way in autumn by covering the tip of the shoot — which makes the best plant — or by half cutting through the joints and pegging them down. In this way quite a number of plants may be got from one shoot. But, as is generally the case, nature's favorite way is the best. Many of the climbing roses can be multiplied very easily thus, as also can gooseberries and currants.

Autumn, then, is a sort of spring, a first spring, preparing for spring proper. Seed is sown and seed germinates. Life-blood is conveyed to roots and twigs, and buds form and swell. August is perhaps a more restful time in nature than late autumn. Of course, the ripening of fruit is a part of the activity of trees, but it has to be remembered that the ripening and maturing of fruit are rather different things. After they have reached a certain point, fruit and seed have in themselves the power of maturing. In the ripening — that is, in bringing the fruit to the full size and development — the tree plays a part, but when this stage is reached the fruit as it were matures itself. Its consistency changes and it becomes more palatable. This maturing of fruit is, however, not quite the same as the drying of seeds, though it is like it. Wheat is left in the field in sheaves and shocks in order to mature, in one sense of the term, but the maturing is partly connected with the loss of moisture. The less moisture there is in a grain of wheat and the more polished and transparent it looks, the better is its quality. It is said by the millers to be "stronger." However, no wheats grown in a humid climate are as strong as those grown more quickly under the hotter suns of the great plains.

At every season of the year some sort of growth is proceeding. One of the most curious tests of this is the sprouting of bulbs or tubers. In no way can some bulbs be made to grow before their proper season. The bulb has to go through some mysterious process within itself before it is ready. The bulbs have been called by a name first given to coal, "bottled sunlight." In a sense they are: that is to say, the leaves have taken in sunlight, changed it to their use, and transferred it to the bulb, in which it will serve as food for next year's growth. It is always to be remembered in botany that the sun and air, through the leaves, do more for the plant in respect to food than the water and earth acting through the roots. We may be allowed, then, roughly if not with scientific accuracy to call the bulb or tuber — for a potato is like a snowdrop in this respect — "bottled sunlight."

But this sunlight in the bulb has to go through some untraceable change, working right through the winter months, before it can be converted into growth, into leaves and flowers All efforts to force these bulbs unduly have failed, and the only method of getting flowers from them out of date is to freeze the bulbs. When they have come to their full maturity it is easy to stop them sprouting. All that is necessary is to lower the temperature sufficiently and, obeying the law of self-protection, they will not shoot till warmer and safer conditions are promised.

The circle of the year is much less definitely marked into seasons for this thing and that than is generally supposed; and the continuity has a great deal to do with many farming and gardening operations. It may be said that sowing and planting can be done from September, or earlier in mild climates, to the end of the first week or two in May — that is, during three-quarters of the year; and, of course, in the garden where successive crops are required sowing continues much later than the first half of May. Equally of course, it is not to be imagined that these things are to be done in bad weather; and two periods, an autumn and a spring, mark themselves out, but it is true that there are seven months or so of the sowing and planting season. August is perhaps more like the end of the year than any other.

Many birds molt at this time and lose their vigor, whereas they return to first plumage and full vigor a month or so later.

As with animals, so with plants. The fall of the wheat harvest, which never begins before the latter half of July and is often not completed until September in northern states, is the sign of the end of the most important stage in the year. After this a new vigor begins to appear again; and, as has been said, the fall of the leaves, though also due to other causes, is one sign of it. In modern farming it is becoming the custom to plow up the land with the utmost speed, indeed, it is not uncommon to see the plows at work in a field before the wagons have left it with their load of sheaves, so quickly does the farmer make one operation follow on the heels of another, realizing that he cannot too soon open his land to the air, add manure, and, with the help of the weather, prepare a seed-bed for the grain he is about to sow. Under every tree and bush, and to some extent over the fields, nature herself spreads a fertilizing substance. The leaves when they fall have parted with almost all their useful substance except lime. We have already seen, when we discussed the soil, how very necessary lime is to its fertility. This is partly supplied by the fallen leaves, so that nothing is wasted. What is taken out of the ground is returned with much else that comes from the air and sun.

THE BUDS FOR THE NEXT YEAR'S GROWTH ON THE OAK, THE BEECH AND THE EDIBLE CHESTNUT

With the help of glass, man can in some degree defeat the seasons, but he cannot do so altogether The French, who are intensive gardeners, consider that the year very properly is made to begin on January the first January is one of their busiest months, and their frames are full of seeds that germinate and grow at an astounding speed before that month is passed With this school of gardeners also August is regarded as the end of the season In almost every part of the wheat belt we may see on every hand signs of the continuity and overlapping of the seasons The first green blades of wheat are springing up on the tilths. At the same time green crops, such as corn, are hardly yet ready to cut. When the last leaves are falling from the stems at the end of November we may find the honeysuckles putting out long leaves, and the catkins are very apparent on the hazels Quite a number of weeds are in flower through the winter. As soon as the days begin to lengthen, gardeners become busy.

The moral of it all is that the land is capable of bearing successive crops within the year. We may have green crops for the stock from early summer till late autumn. One of the most delightful sights of autumn is to see the clover, which was in the ground along with the wheat, begin to cover up the hard ridges of the stubble But more crops than clover can be grown simultaneously to be reaped successively In New Jersey, for example, on some of the best farms, two successive crops of potatoes are grown on the same field

Nothing is more kindly than our spring-like autumn, which gives us a double chance of getting a fair harvest. Even those who have just begun to dabble in gardening are told that they may either sow their seed, as nature usually sows it, in autumn for flowers in the next year, or in the spring for flowers in the same year This, too, is a lesson in the seasons; and the nature of the season is the very first thing to be learned by all those who have any traffic in the ways of plants.

ANIMAL HELPERS OF MAN

The Bactrian camel of the desert regions of Central Asia.

SOME ANIMAL HELPERS OF MAN

Man's Miracles of Mastery — The Animals he has Trained to do his Work on the Fringes of Civilization

SHOULD MORE SPECIES BE TAMED?

IN this age of electricity, steam and gasoline, man remains strangely dependent for his existence upon animal life He and the ants are the only living creatures that have pressed other living creatures into bondage. The ant makes slaves and keeps herds of "cows," and maintains a highly organized communal life The slave-making ants become in time wholly dependent upon their servitors; man in many a land would perish were he suddenly deprived of his allies of the lower orders Indeed, some scientists foresee a day when civilization may be menaced by lack of animal help; the day when we shall have exhausted all the vegetable fuels, such as coal and petroleum, when we shall be driven back to reliance upon animal labor, and find the supply insufficient. From this quarter comes an earnest appeal to the present generation to "domesticate, domesticate, domesticate," and add new animals to the list of those which serve us in the production of power.

Many miracles have been achieved by the men who have attained to mastery of the wilds. Man's attitude towards the animals that he has subjugated has been wiser than his attitude towards his fellows. A Napoleon seizes upon the biggest and most powerful men in many nations, forces them into his armies to be shot dead or maimed for life, and leaves a continent bereft of its finest physical types of manhood, so that during the two or three generations following the minimum standard of height admitting to the armies of Europe had to be lowered. In his dealings with the beasts man has shown more enlightenment.

He has taken the best for the sires and dams of his flocks and herds; it is the inferior that he kills. He prevents the inferior types from increasing their numbers. He creates a new animal in the mule; he multiplies breeds of animals and birds by the hundred He has improved upon nature as well in regard to animal life as in regard to vegetable life. He goes into the jungle and brings home captive the lord of the animal world — the colossal elephant — and in a few months makes it his willing slave, he polices his body with benevolent bacilli. He sends the bloodthirsty cheetah to pull down the fleet-footed stag, and himself becomes, as it were, the foster parent of salmon and trout and oyster and lobster. He makes the camel his ship in the desert, and harnesses the minutest of nature's children, the microorganisms of the soil, to grow for himself a dish of vegetables or a bouquet of flowers. He has taught the otter and the cormorant to fish for him; he has lured the fowl from the jungle and made it as prolific of eggs as a beetle The yak and the reindeer, the Bactrian camel, and the dog are his pack animals in the frozen wilds; the true llama owes him its existence. The beauty-birds, such as the peacock, have surrendered their liberty to become contented denizens of his home; the duck and the goose and the swan forget that they and the wilds ever were associated. His are the cattle upon a thousand hills, and practically every species of sheep in the world that has value for wool and flesh, and the strings from which the violinist woos divine melody, is of man's selection and development.

The same skill that has produced from the hog-maned, weedy animal of the steppes the satiny grace of the speeding racehorse, has evolved also the comfortable domestic pig from the wild pig of the forest; has made the caterpillar of the silk-moth yield robes of luxury, and has caused the bee to surrender honey and wax as rent for the home that man provides. He claims the service of the ladybird to patrol his plantations and his rose-garden, he tames the polecat into the ferret to rid him of mice and rats, a task to which he also has educated the cat and the mongoose; and he nurtures the civet to yield him perfume as if the animal were a flower

Today we are in some respects less dependent than we have ever been before upon the services of the animals which merely labor for us, yet civilization is conducted, upon its arid and Arctic fringes, by camel labor and by yak labor; and the post office with all its multitudinous resources, has to depend in winter, for the distribution of the mails, upon teams of dogs, a means upon which the people of the far Northwest have also to rely, the highest hope of these semi-arctic folks being that some day the villainous, half-wild wolf-dogs of these desolate lands, which in time of hunger turn and rend and eat their masters, will be supplanted by the gentle reindeer and the railroad.

Which is the most valuable of the animal legacies from the unstoried past? We may leave to another chapter the animals with which we are all most familiar, and confine ourselves here to those that keep business going in its farther ramifications Obviously the decision must lie with the camel and the reindeer. The mahout who loves his elephant would demur to this conclusion. But, taking all-round utility, and leaving out of question the matter of lovability, intelligence and fidelity, the palm must be awarded to one of these two animals, camel or reindeer.

The camel is the greater puzzle. The puzzle is not as to distribution, that has been triumphantly solved. The family exists now, in numbers, only in the desert regions of western Asia and North Africa, but its relatives flourish in the Andes and on the temperate plains of South America in the form of alpacas, llamas, vicuñas and guanacos Vastly as they differ superficially, the animals are closely akin in all essentials of structure, even to the peculiar complex stomach adapted for water-storage Widely separated as are the two groups, we can account for it


THE VICUÑA

The case cannot be more succinctly stated than in the words of Dr. Alfred Russel Wallace, who has shown that the discovery of fossils during the last generation in North America makes clear the probable development of the family in that continent from a smaller and more primitive type of animal. The strata of the late, middle and early Tertiary periods reveal early forms combining the characters of all the hoofed animals, from the swine and the hippopotamus to camels, sheep, deer and antelopes. It is therefore clear that in all likelihood the camel and llama tribes originated in the central United States, where, towards the end of the Tertiary period, they became extinct. Happily, prior to this catastrophe, some of the true camels had migrated to the eastern hemisphere, probably by way of continuous land in the North Pacific, and have left as their only survivors the camel and the dromedary. About the same time, and probably driven to migrate by the same adverse conditions which led to the extinction of so many of their allies, the llama group passed southward along the mountain ranges into South America, where they have found suitable

conditions for their survival south of the equator, in the high Andes and on the arid plains of Patagonia It should be added that there is high authority for the belief that possibly the Arabian camel originated in India

Whatever the place of its origin, we find this animal existing now, not only in Arabia, but in South Africa, where it has for many a day carried the mails in the remoter parts and supplied the police with mounts and hauled their vehicles; and in Australia, where it has helped to establish the prosperity of many of the up-country districts by carrying the wire necessary for fencing out the rabbits, and bringing down the wool upon which the settlers' fortunes are staked. It is bred in great numbers in India; it is an industrious servant in the Canary Islands; it is at work in parts of Italy. Wherever there is dry, sandy land with scanty herbage, or, say, even absence of wet, cold climate, the Arabian camel can flourish We rule out sub-arctic conditions, of course, that suit only the Bactrian camel.

As the camel is so generally employed by man, what is the puzzle to which reference has been made? The puzzle is that man should have evolved an animal at once so valuable and yet so unmitigated a brute. There are bad-tempered and unreliable dogs, horses, cattle and asses as exceptions, but practically all camels are ill-conditioned, treacherous and sour-tempered. They seem to go through life with a grievance against all the rest of the world. It is as natural for a camel savagely to gnaw the hand or arm of its master as it is for an intelligent horse to whinny with pleasure at his approach. Well fed, lightly loaded, kindly treated, the camel will "savage" a rider whom it passes on a narrow path.

THE GUANACO

For thousands of years this animal has been domesticated — there is not a really wild Arabian camel in the ordinary acceptation of the term The great herds that roam unbroken in northwest India, in the Soudan, and in Somaliland are as much domesticated as the flock-master's sheep Yet nothing improves the intelligence or temper of the camel In that respect it is probably unique Man has improved the intelligence of the horse and dog, and, indeed, that of practically all the mammals he has taken under his control Perhaps the fault in regard to the camel lies with man. He has bred only with a view to stature, strength, speed, endurance, to milk-giving qualities, to the abundance of hair, but not with a view to developing intelligence; and as the camel is not left to shift for his own living, and escapes, therefore, the stern struggle for existence that wild animals have to brave, he has not needed, of his own initiative, to develop brain-power.

But the camel is indispensable to the East. British and French armies in northern Africa have their camel corps It is the only animal that can cross the desert. With its broad pads to prevent it from sinking into the sand, with a nasal defense against the sandstorm rivaling that of the hippopotamus in the water, with capacity unique among domesticated animals for withstanding the effects of thirst, it bears the burdens of the merchandise that has to be carried across otherwise impassable desert. It is not alone a beast of burden to its owner. The swift dromedary, keeping up its eight or nine miles an hour for hour after hour, is the Arab's charger in the wastes. The female camel yields him milk and cream and butter. The milk is rich and sustaining, though it cannot be used in tea or coffee, owing to its curdling.

The butter-making is an extremely simple process Separated cream is put into a skin bag and hung upon the saddle at the beginning of the day's journey, and upon the resting-place being reached the cream has become butter, churned by the action of the camel in walking

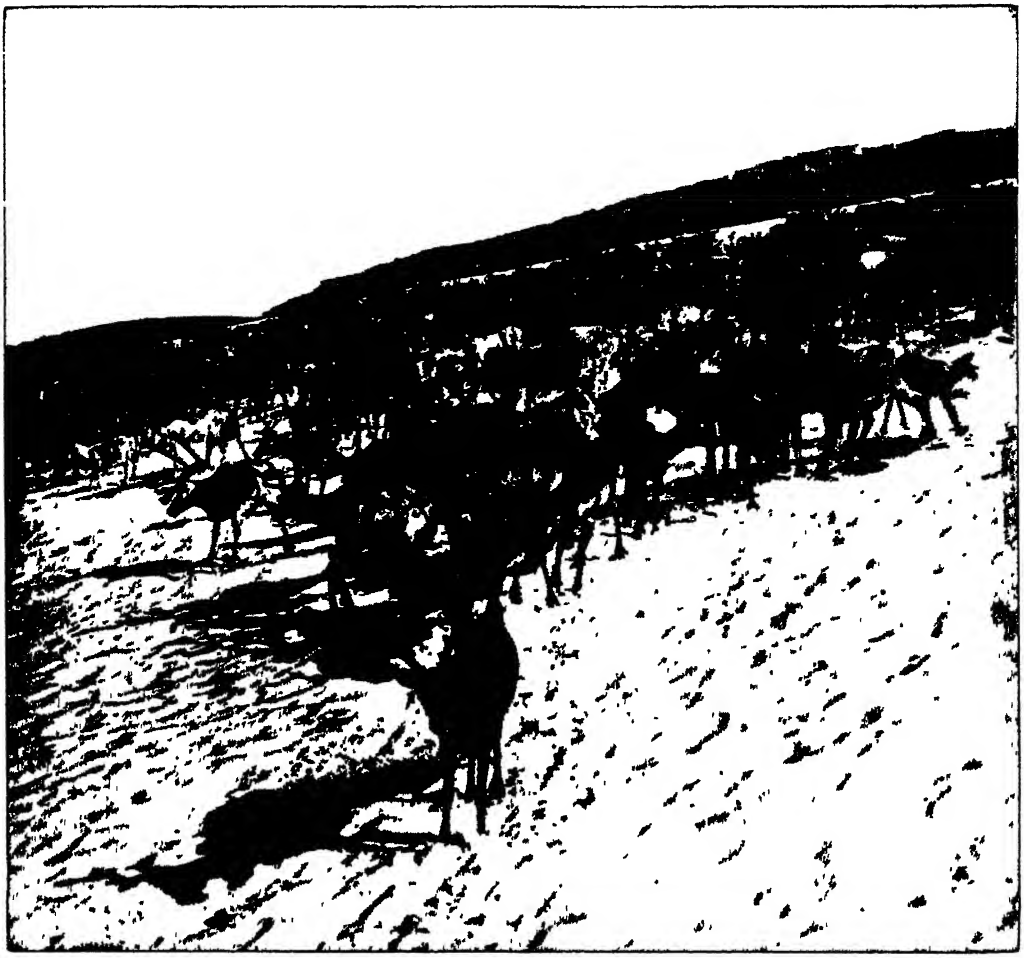
The hair of the animal is woven by the Arabs into cloth, and it makes the best of brushes The very dung is utilized, and often constitutes the only fuel in the desert With it the Arab makes his fire to cook his food; and it is betraying no trade secret to mention that the peculiar odor of a certain high-priced tobacco arises from the fumes of fires of this sort, over which it is "cured" The food of the Arabian camel is of the most meager type. The animal can eat whatever vegetation the inhospitable desert affords. No thorn is too formidable, no vegetation too dry or tasteless. The animal prefers this form of food to others

Not long ago the present writer stood to watch a camel at liberty in a field of luscious grass. The horses pastured there stood afar off, gazing with looks of terror at the stranger, revealing once more that curious antipathy with which the camel always inspires the horse. The camel made straight for the low bushes on the edge of the field, and browsed upon the thorny growths which grew there, the grass had no meaning for this strange beast. There was water trickling through the field deep down in a ditch, but the camel disregarded this. Now, the camel in the East will only with the greatest reluctance cross the tiniest of streams, showing how persistent is the instinct of this desert-reared mammal.

But, at times, of course, it does have to cross rivers. The life of Slatin Pasha, the Austrian-Egyptian soldier, on his flight from the Khalifa's citadel in the year 1895, after eleven years of captivity, depended upon his getting his camel over a wide river His Arab friends saw to that for him They took Slatin across in a small boat. They emptied their water-skins and inflated them, and tied these about the neck of the camel, and buoyed him over. But that thrilling flight emphasized the inferiority of the Arabian to the Bactrian camel in rocky country. The one camel that Slatin possessed during a most critical part of his journey, cut one of its feet almost to pieces on a rock, and Slatin had nearly to strip himself to bind up its wounds. He had learned the trick when he was governor at Darfur, where he had seen the natives put a sort of shoe upon the injured feet of camels, a shoe of cloth and leather.


A YAK FROM CHINESE TARTARY

The Bactrian camel, instantly distinguishable from the Arabian by the fact that it has two humps, not one, is to cold, rocky and hilly country what its Arabian congener is to the scorching desert. It has shorter and stouter limbs, and smaller, tougher feet. But in endurance it differs little from the other. It can survive the bitterest cold; it feeds upon the sparse herbage of the steppes, and revels in brackish water which very few other animals could drink. It can make its bed in the snow as comfortably as the Arabian animal can in the sand. But it is not indestructible. Col. Frederick Burnaby, on his famous ride to Khiva in 1875, found that of 14,000 camels requisitioned for a then recent Russian expedition, nearly all had died from hardship. Still, with reasonably careful treatment, the Bactrian camel is a marvel of endurance at a minimum cost to its master.



A HERD OF REINDEER IN NORWAY

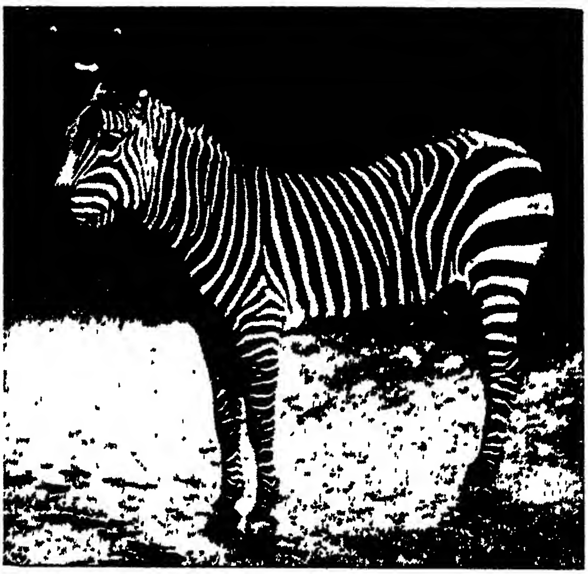
There are supposed to be no wild camels in existence, but in the desert regions of central Asia there certainly are wild camels, descended probably from animals that once were domesticated. It is supposed that their ancestors escaped the frightful sandstorms which overwhelmed the district known as Takla Makan, some two centuries ago. They have the greatest fear of man, and none of them, so far as is known, has ever been caught, for the simple reason that no horse can approach them in the deep sand of the region they frequent. The Tibetan desert has its free-roving camel, and this, it is thought, may be a veritable wild camel, descended, perhaps, from the stock which early man, thousands of years before history, first tamed.

Asia and Africa give us the biggest members of the camel family, but the South American representatives, though smaller, have something of the family vice. The llama is the one animal that spits. It does so with lamentable force and accuracy; and the petted llama of the Zoölogical Park in New York is an offender, so that he has to have a double rail between himself and the public.

When we speak of the llama we have to include four forms — the llama proper, the alpaca, the guanaco and the vicuña. The llama and the alpaca are the domesticated members of the group. It seems almost incredible, but the llama was the only beast of burden in America when the Spaniards first landed The sight of a horseman filled the Peruvians with terror.

Such a phenomenon represented a centaur to their imagination For thousands of years the llama was the Peruvian's steed and pack animal and the alpaca was his sheep The male llamas only were taken to work, the females being left then, as now, in comparative freedom upon the hillside, where, during the absence of their lords, they might be visited by the larger and more powerful guanaco. It seems clear that the llama is the domesticated descendant of the guanaco, as the alpaca is the descendant of the vicuña

The Peruvians looked as carefully to the breed of their animals as we do; the Incas killed the old and the inferior specimens, rooted out bad colors, and preserved the animals of finest size and form And that went on until the Spanish invasion By that time the land possessed boundless herds of both animals It was not until Sir Titus Salt discovered the value of the wool of the alpaca that this commodity became marketable in Europe. It is now much used for linings, etc.


THE MOUNTAIN ZEBRA OF CAPE COLONY

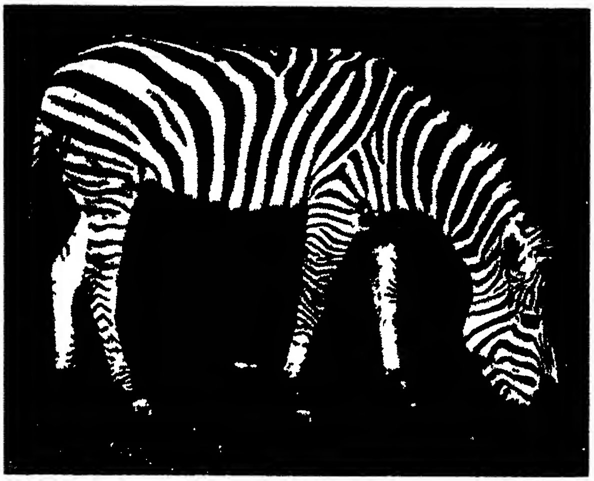
All the llama family share the distaste of the true camel for luxurious living. The true llama supports itself on the sparsest of food; the vicuña, when vegetation is plentiful, seeks the higher range of its native mountains, where it is poorest; and only in the heat of summer, when the sun has dried up all vegetation in exposed situations, does it descend to the higher valleys. The guanaco, too, haunts the mountains, where food is never excessively rich. It is this animal, it will be remembered, which has the strange habit of repairing to a definite spot to die. Darwin was the first to allude in print to this remarkable habit.

Highly valued as is the camel family in the Old World and the New, the reindeer runs it close in the esteem of its master in the northern regions of both the eastern and western hemispheres To the Laplander the number of his reindeer represents his wealth With a thousand of these animals he is among the plutocrats of the land; the man who owns half as many is of the middle classes; while he that boasts but forty or fifty is content to merge his small herd in that of another, and work for the owner of the greater number. The reindeer has been captured from the wilds, a creature of the tundra, the snows, and the waste places of Lapland It can draw a heavily laden sledge, or carry a man or a substantial package upon its back, and travel at the rate of eight to ten miles an hour for several hours in succession Its advantage over the dog is that it finds its food where it rests, while the food of the dog must be taken with it. The reindeer yields milk, meat, and leather for boots, clothing, bedding, the tent and the boat, and its sinews serve as ropes.

Seeing that the reindeer is to him horse, cow, sheep and goat, it is strange that man has not improved the animal more, but it is a fact that the domesticated reindeer is never so fine an animal as its free relative. This is especially the case in Lapland. In Siberia, too, where the domesticated animal is bigger than that of Lapland, it is smaller than the one that roams at large. Doubtless this is owing in the main to the wider, indeed unrestricted, range of the free animal. He roams at will up the mountain side in summer and descends to the plains in winter.

Where sheep and cattle would starve he finds a generous diet of lichen, or the reindeer moss, and other rough herbage When hard pressed the reindeer will even pose as a carnivore, and, in time of famine, when the lemming is on the march, reindeer eat thousands of these little rodents.

The reindeer's is a hard life, but he is beautifully fitted for it, and on the whole his lot, it is pleasant to reflect, is not worse with man than when he is in a state of liberty. Indeed we may claim to have done something to keep him alive, for this animal is sadly subject to anthrax, a disease which has in the past carried off enormous numbers. Happily the scientist has come to the aid of the Laplander and the man of Siberia, and has taught him to inoculate his herd, so that this deadly plague need no longer rob him of his all.



THE QUAGGA OF DAMARALAND

The reindeer seems to have a still more widely extended dominion to conquer Thanks to the indomitable Dr. Wilfred T Grenfell, the missionary physician, it has been introduced into Newfoundland and Labrador, where it is thriving wonderfully Alaskan and Canadian Eskimos are taking up reindeer-keeping, and the governments of both Canada and the United States have recently begun experiments on a wide scale. Should results in this direction be satisfactory, probably both governments will feel justified in extending operations, and import the yak for the Barren Lands.

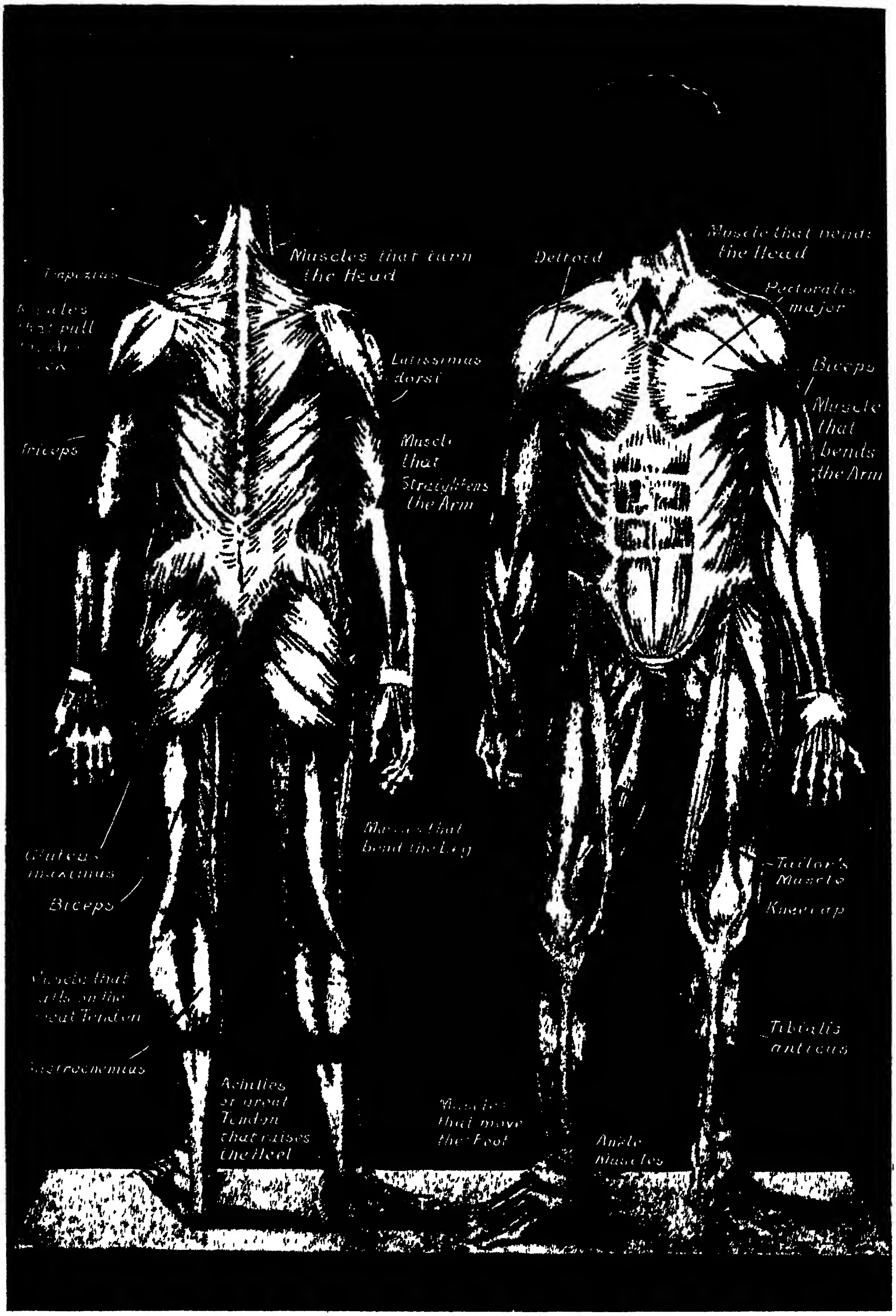
This animal, peculiar to the elevated plateau of Tibet and the adjacent districts of China, exists in freedom in vast numbers where it is not frequently hunted. It is an indispensable member of the circle of domesticated animals. It seeks the wildest, most desolate regions in the inhospitable country to which it belongs, and can endure an extraordinarily low temperature on the roughest diet. It has long been bred in captivity, and man has brought his art to bear to modify the characteristics of the animal By introducing into his herd of yaks the blood of the true cattle, he has succeeded in producing an animal that can bear heat as well as cold—an advantage the true-bred yak does not possess. The yak, which is a massively built animal, reaching a weight of 1000 pounds and a height of six feet, can carry heavy burdens over mountain roads that stagger even the stoutest mule.

There remains only the zebra group for consideration in our list. Here we have the plains zebra distributed over eastern Africa from Abyssinia to Zululand, and thence westward to southern Angola; the mountain zebra, now reduced by shameful slaughter merely to a few protected herds, Grant's zebra, now nearly or quite extinct, Foa's zebra, a rare species, and Grevy's zebra, the largest and finest species of the group, an animal measuring 13 hands, or 52 inches, at the withers. The zebra, as we have seen, has been broken to harness and is impervious to the deadly tsetse fly.

Colonel Sir David Bruce has recently been experimenting in Nyasaland on his third campaign against sleeping sickness, and if he succeeds it should not be difficult to render animals immune. Be that as it may, the zebra has high economic possibilities; and the killing of it ought to be unlawful. Had it been an Asian animal, the zebra would have been tamed ages ago.

It is hardly necessary to add that the zebra and quagga, with the ass, are all members of the horse tribe, and merit the consideration due to kinship with one of the most faithful animal helpers of man.

THE MUSCULAR SYSTEM OF MAN



THE PRINCIPAL PARTS OF THE NATURAL MACHINERY THAT WORKS THE HUMAN BODY
(A diagrammatic representation)

MAN'S THEWS AND SINEWS

How Our Muscles are Fed, Increased, Held in Reserve, Used, Poisoned, Purified and Controlled

THE MARVELOUS MACHINERY OF THE BODY

THE bony framework of the body, its joints, and the muscles which act upon them, constitute, from one point of view, a single system, the function of which is mechanical and motor. No less just is the view which looks upon muscles as simply the "end-organs" of nerves — as merely the mechanical structures developed at the ends of motor nerves to do their bidding. Looking at the body as a whole, and trying to grasp broadly what has been called the "philosophy of the organism," we must retain both views.

Primarily, muscles are for motion, as bones are for stability, though we saw that bones have a secondary function which is no less essential to the maintenance of the body, and we shall find that the same is true of muscles. The motion is almost invariably that of one bone upon another, or of groups of bones upon each other, but there are some interesting exceptions which may be briefly noted — exceptions none the less interesting because they partake, in some degree, of the character of ancestral relics or survivals. The muscles in question are superficial, and their business is with the skin or its outgrowths. A possible advantage of being able to twitch the skin is that it affords some protection against insects, those great enemies from the invertebrate world.

Thus, the horse has an entire sheet of muscle covering its body, and this is represented in ourselves very imperfectly, first, by a thin sheet of muscle in the neck, and second, by a tiny sheet of muscle, the presence of which any of us can infer for himself, if he will try to wrinkle the skin on the inner side of the palm.

The muscle in the neck has the power of contracting the skin there; it is supplied by the nerve of expression, and comes into the group recognized by Darwin as the muscles expressing anger. Its action may sometimes be seen in an angry dog, but it is seldom developed in man.

At a somewhat deeper level are certain other muscles, which are also unconnected with the bony system, and do not act upon joints. There are thus three straps of muscle attached to the outer ear, on either side of the body, which in the lower animals would have been employed for the detection of the direction of sound, and for its more easy reception, but they are also decadent in man. Much more important are the superficial muscles of the face and lips and scalp, and the muscles around the eyes. These form a complex and important system, all controlled by the nerve of expression, and all extremely well supplied with fibers from it in proportion to their very small bulk.

They are essentially the social muscles, for in the absence of anyone to impress there is no occasion to express, and their functions are almost wholly those of expression. Thus, the upper eyelid naturally falls, by its own weight, if it be not raised by the special muscle which is attached to it from behind. The muscle which encircles the eyelids and can "screw up" the eyes, is not required for simple closure, but has considerable functions for that intense closure which expresses an emotion of horror or disgust. Life is persistently economical, and no doubt the muscles of the lips, for instance, are employed for more purposes than expres-

sion, but the general statement is true that expression is the primary function of the muscles of this group, and only on the ground of the incredible minuteness of difference between its shades can we account for their very rich nerve supply.

It seems fair, also, to include the muscles associated with the hairs in this category or near it They are very tiny, and lie nowhere near bones or joints. They are no more under the control of our will today than the muscles of the outer ears, but it may be that the power of throwing them into action voluntarily exists among the lower animals It is not in a sentence, however, that we shall decide whether the cat elevates its hair in order to frighten its enemy, or as an inevitable expression of the emotion called anger, or partly for both reasons. At any rate, man has muscular slips attached to his hairs, and on occasion they act, and his "hair stands on end" We shall agree that these occasions are emotional, and that this classification is, therefore, probably just. The phenomenon called "goose-flesh" also depends upon emotion, and is due to the activity of skin muscles.

So much for the superficial muscles, sheets, slips or what not, which persist in man, and have nothing to do with bones and joints, but simply move parts of the skin or its outgrowths.

The muscular system that has been placed beyond the control of our will

But there remains a great group of muscles, or muscular tissue, which are not concerned with bones and joints, nor with movements of the body as a whole, nor, indeed, with any act or possibility of the conscious will, but which are, nevertheless, necessary to life.

When we study muscular tissue under the microscope, we find that some specimens of it are marked by a series of transverse striations, running across the long direction of the fibers (or of the muscle cells, as indeed they are), whereas other specimens are non-striated. We further find the remarkable fact that the striated structure is found in all the muscles which we use voluntarily, while the non-striated structure comes from muscular tissue which is not under the control of the will. and the existence of which is probably unknown to most of us. Non-striated or involuntary muscle can only be discussed in outline here, because it is concerned with internal organs, of which we should require to know something first; but it is very necessary to realize that muscle is essentially muscle everywhere, having structure fundamentally the same in all cases, and the function of producing movement.

The most important exception to the general rule concerning involuntary muscle in the body is that muscle which composes practically the whole thickness of the walls of the heart, and which contracts oftener than once every second from many months before our birth until death. The microscopists report that the heart muscle, although it is not under the control of our will, is of the striated type. Though breathing is necessary, and proceeds without the attention of the will, the muscles of breathing can to some extent be stimulated voluntarily and are all composed of striped tissue; thus the diaphragm, after the heart the most important muscle, is also striated.

How the muscular coats of the blood and air passages act involuntarily

But the circulatory system contains non-striated muscle in every part of it except in the minutest hairlike vessels, and this muscular tissue constitutes a coat which regulates the size of veins and arteries, not only apart from the will, but often against it, as when we blush in spite of our best efforts not to. The respiratory system also has important examples of non-striated muscle, controlling the size of the air passages in the lungs, after a similar fashion to that of the arteries and veins. Here, again, we find that the tissue is not subject to the will, and may even contract against it, as only too often in nervous asthma, where the difficulty of breathing depends upon the involuntary and morbid action of the non-striated muscular tissue in the walls of the air vessels.

No less important is the non-striated or smooth muscular tissue in the walls of the digestive canal The gullet is thus lined, and though we swallow voluntarily, and by means of striated muscle, it is smooth muscle and involuntary action that drive the food from the beginning of the gullet into the stomach. That receptacle is similarly lined, and the lining is invaluable in stirring the stomach contents during digestion. For many yards thereafter the digestive canal proceeds, lined with smooth muscle throughout. And in various other parts of the body we find smooth muscle, as, for instance, in small quantity behind the eyeball, which it may cause to protrude; in the wall of the uterus and elsewhere.

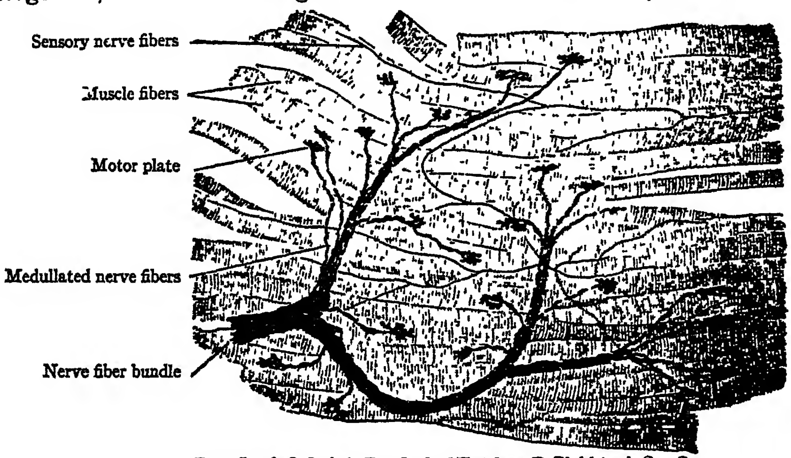
From Gerrish's *Anatomy*, Lea & Febiger

SUPERFICIAL MUSCLES OF THE HEAD AND NECK (Testut)

Though the whole system of smooth (non-striated) muscle is beyond the reach of the will, it is not independent of nervous control. There are certain agents, such as forms of electricity, which can stimulate muscular tissue directly, without nervous intervention. But such stimulation never occurs in the normal life of the body. All muscle cells whatever are the end-organs of nerves, as we began by saying, and normally they neither act by themselves nor in response to any but nervous stimulation. This has lately been proved true even of the muscle of the heart, which many have long supposed to be independent of nerves altogether, so far as the origin of the beat is concerned, though we know, of course, that nerves can and do affect the beat. It is true that the heart continues to beat though all the nerves running to it be severed. But this beat is not originated by the muscle itself, but supposedly by special groups of nerve cells which are found in the substance of the heart. It is definitely proved, then, that muscle originates nothing. It is always and only a servant, and in the natural life of the body it takes orders from nerves only. The involuntary or smooth forms of muscle are just as much subject to the central nervous system, including certain portions of the brain itself, as are the muscles of the fingers, but the conscious will does not reach them.

This is very far from saying that consciousness does not affect them, or that they are independent of anything that happens in the uppermost part of the brain. We have already noted, for instance, how feeling may cause a blush. And we now know ways in which these involuntary muscles may be controlled and willed to do what we will, though the will of their owner is not concerned. That will is indeed the obstacle. But if the person be hypnotized or, short of actual hypnotism, be put into a state in which the will is, as they say, "short-circuited," or evaded, or put to sleep, then ideas put into the patient's mind, either by himself for himself or by someone else with his approval, can directly control the working of the involuntary muscles thereafter. Thus, for instance, asthma may be controlled, or the movements of the digestive tract, and those results may be attained which the utmost efforts at willing on the part of the patient made only more impossible. This is not the place in which to look more closely at these astonishing and only lately defined facts; but we must note them here when we speak of smooth muscle as involuntary. Involuntary it is, but inaccessible to the will, by denial of the will, it is not — curious and significant paradox.

In the essentials of microscopic structure, all forms of muscle, striated and non-striated, agree. A muscle is essentially



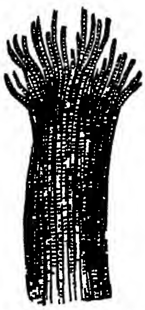
From Lewis & Stöhr's *Text-book of Histology*, P Blakiston's Son Co

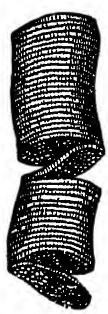
MOTOR NERVE ENDINGS OF INTERCOSTAL MUSCLE FIBERS OF A RABBIT MAGNIFIED 150 TIMES

a group of elongated living cells, very long and narrow, each with a nucleus, and each bound to its neighbors and arranged lengthwise in the direction in which the muscle is required to pull These cells are supplied with nerves, the proportion of nerve to muscle varying widely As much nervous tissue, for instance, may be found in a small muscle of the ball of the thumb as in a large muscle of the thigh. The proportion of nerve would therefore seem to depend on the variety and delicacy of the movements which the muscle will be called upon to perform. Or perhaps we should reverse the statement, and say that the richly innervated muscle is that which we can put to the most delicate and numerous uses. Muscles are further endowed with a second and wholly distinct set of nerves, which are entirely different in function from those just named.

The first and most evident group of nerve fibers found in muscular tissue is motor in function, and these constitute the "nerve supply" of a muscle in the ordinary use of that term. If these nerves be stimulated the muscle fibers contract, if they be divided the muscle is paralyzed. But we have lately learned that all muscles are supplied with a second set of nerves, whose function is not motor but sensory. These nerves feel, and that which they feel appears to be the exact shape and condition of the muscle at any given moment. They keep the central nervous system informed as to the whereabouts of its servants, and their obedience or disobedience to its orders.

A certain amount of connective tissue, loose or strong in structure, lies between the fibers of a muscle, and binds them together. This connective tissue is found in almost all parts of the body, and performs the functions of packing and binding. It is found, also, spread over the surface of muscles, forming a kind of sheath or outer coat inside which they work Connective tissue cannot contract. If muscular tissue degenerates, from any cause, and there are many, its place is often taken, in some degree, by an increase in the amount of connective tissue within the muscle. Thus the bulk of the muscle may be maintained, or even, in some cases, increased; but such a muscle, which may be that of the heart, or any other, is worth little, for no connective tissue, however strong, firm and dense it may be, can contract, and the muscle which cannot contract is nothing.

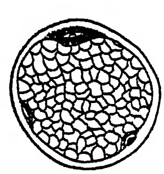




From Gerrish's *Anatomy*, Lea & Febiger

Fragment of a fiber of cross-striped muscular tissue, showing fibrils separated at one end by teasing

Fragment of a fiber of cross-striped muscular tissue, hardened, showing transverse cleavage of fibrils (Kolliker)



Transverse section of muscle fiber showing fibrils, three nuclei, and the muscle fiber sheath (Testut).

The study of development teaches us that muscles are essentially formed from small, roundish, nucleated cells, which become greatly elongated, are arranged in parallel bundles, and acquire the power of contraction. There is evidence to show that certain numbers of these cells occur, in an undeveloped, and thus useless, form in adult muscle; just as we shall discover in due course that a certain number of undeveloped nerve cells occur in the adult brain. In both these cases, and especially in the latter, the facts are evidently most suggestive and important, bearing as they seem to do upon the possibility, utility and limits of education. Unfortunately, we know too little yet of this fascinating subject. But it would appear that a certain number, probably definite and limited, of these cells are found in all or most muscles, and that under certain conditions they are capable of development, even in maturity. And we may yet be able to stimulate to activity such dormant cells in the maimed parts of many of our Great War soldiers so that their bodies may again enjoy their pristine health and vigor.

It looks as if they constituted a natural reserve for emergencies. The intense economy of life forbids their development without occasion, but if we set ourselves to physical development and training we develop these cells and our muscles grow larger. There are many people who become definitely heavier under the influence of exercise, no less definitely than those who lose weight; and the increase of weight is due to the actual development of new muscular tissue It appears that individual muscular fibers do not much enlarge, if at all, and certainly new ones cannot develop from anything but cells predestined to become muscle fibers if they develop at all, and that is what actually happens.

All this throws much light on many familiar facts of physical development which we too often forget. The same conditions, applied to different people, produce different results; nay, if each be given the conditions best suited for himself and himself alone, the results are still quite disproportionate. Probably the natural endowment of potential muscle cells is unequal in the two cases And, further, for each of us there is a natural limit of muscular development which we cannot transcend, as many a disappointed aspirant to muscular honors has discovered. The foregoing theory would suggest an evident interpretation — that one may, by labor and suitable nourishment, develop every possible muscle cell in one's body into an active, contractile muscle fiber; but when that has been done, nothing whatever will make us any stronger. If these simple and reasonable considerations were known to any but a few physiologists, much injury of many kinds, especially to growing boys and young men still short of complete development, might be averted; which end may these pages serve.

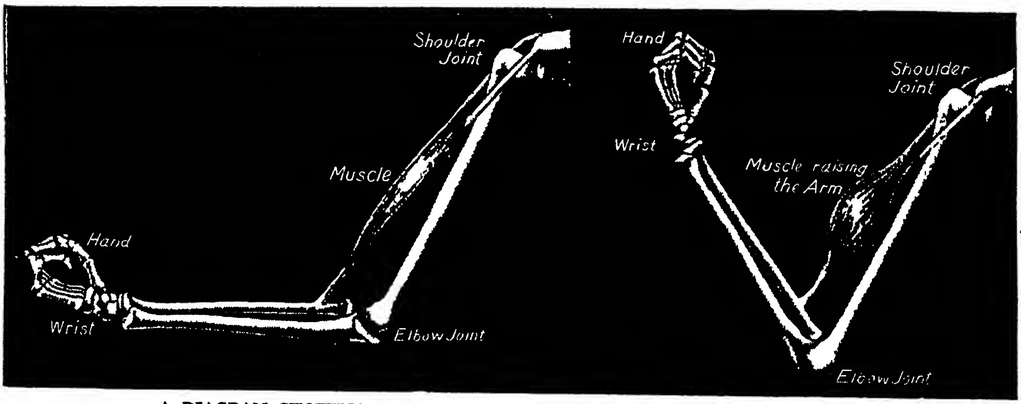
It must be remembered, also, that the normal body is not constructed and developed by fits and starts, without balance between its parts, but is a coördinated whole. There is normally an adjustment between the size of bones, the size of muscles, and the blood supply of both. To develop muscles unduly, while proportionate enlargement of the bones is impossible, may be useless and dangerous. To develop the muscular substance of the heart, while the size of the arteries which supply that substance with blood remains unchanged, may simply be to insure subsequent degeneration, probably not long delayed; and the last stage of that heart is much worse than the first. From this understanding of the "philosophy of the organism" there follows the important truth that the just period for physical development, an admirable and useful thing in its way, is during the early years of growth and construction of the body as a whole. Growing bones can respond to use and exercise and the increased blood supply which these involve; but the length, for instance, of adult bones is determined forever. And the further principle may be inferred, that since the body is a purposeful whole, the best manner of developing any portion of it, such as the muscles, is not to isolate that portion and concentrate upon it, but to put the body as a whole to those purposes which require the use of the portion in question. The upshot of which is, in a word, that youthful play is the one and only perfect and natural way of developing a fine physique.

Our statement of the constitution of muscular tissue, striated and voluntary, or non-striated and involuntary, is not complete unless we mention the supply of blood-vessels which every muscle requires, and also the supply of lymph vessels, or "lymphatics," upon which chiefly devolves the function of carrying away from the muscle certain of its waste products. The circulation in the lymphatics is markedly improved by movement, and languishes when muscles are not employed. But "passive movement" — *i.e.*, being moved — and intermittent pressure largely succeed in keeping the lymphatic circulation sufficiently brisk, and this physiological fact largely underlies the well-known utility of massage, especially for persons who, for any reason, are prevented from using their muscles and promoting the lymphatic circulation in the ordinary way.

Such being the various constituents of muscular tissue, we must face its characteristic and astonishing problem, which is its power of contraction Where the muscle may be, what it pulls upon, whether stimulated through the will or without it or against it — these differences matter not We may take any single muscular fiber anywhere, from whatever source, and consider its case, provided that we consider along with it the nerve fiber that supplies it, for a muscle, we repeat, is the end-organ of a nerve It is a simple matter, having first killed such an animal as a frog, to remove a muscle and its nerve from one of the limbs, and to keep them alive for some time, especially if they be kept moist with water containing a small proportion of salt. This is called a "nerve-muscle preparation," and we have not yet learned the last lesson which it is capable of teaching us.

The chief facts which such observations, aided by the microscope, have elicited hitherto are as follows. The muscle fiber shortens and thickens when it contracts The contraction normally follows upon the stimulation of the motor nerve of the muscle. Contractions which appear to be due to direct action on the muscle itself are almost invariably not so, being really due to stimulation of the nerve endings in the muscle. Galvanic electricity, however, can stimulate muscle directly. Hence its medical use in maintaining the nutrition of muscles whose nerves have been thrown out of action, until such time as those nerves recover. The response of the muscle to nervous stimulation is quick, but not instantaneous; there is a latent period, which may last for perhaps one-hundredth of a second. During that period, of course, rapid and essential chemical processes are occurring in the protoplasm of the muscle fibers, processes which it was the business of the nerve to initiate. This latent period is capable of much variation, and is longer, for instance, in fatigued muscle

There is no limit, however, to the inquiries which can be made at this point, for there is the whole range of drugs and food materials with which to experiment, observing their action on the stimulation of the muscle, upon its fatigue and recovery, the rapidity of its contraction and relaxation (which is mostly due to elastic recoil), its response to poisons, stimulants, and narcotics, and to different kinds of food, and at various levels of temperature. A little writing point can be attached to the muscle, and made to mark the records of its successive contractions on the blackened surface of a revolving drum, the rate of which can be controlled, while a tuning fork, or some other device, may register fractions of seconds beneath the record made by the muscle itself. The stimulation of the muscle can be controlled by an electric switch, and with such an apparatus as this a lifetime may easily be devoted to research which ever more and more helps us to understand the nature and conditions of our lives.



A DIAGRAM SHOWING HOW THE BICEPS MUSCLE RAISES THE FOREARM

A contracting muscle does work, spends energy, for it moves things — itself, if nothing else. Like any other machine, it therefore requires to be supplied with energy, which in the case of a muscle we call food, and in the case of a steam-engine we call fuel, but which is essentially the same in both cases The principal fuel of muscles is sugar. The starch and the various forms of sugar in our diet — as also, if necessary, parts of the proteins or albumins of the diet — are all converted into a definite and characteristic form of sugar which is called "glucose," and is a normal and necessary constituent of the blood. Glucose is the special food or fuel of all muscular tissue, voluntary or involuntary, including the heart. The blood which enters a muscle carries glucose, and doubtless other substances, to it, and the nervous stimulation of a muscle is like the spark to tinder, or the blow to dynamite.

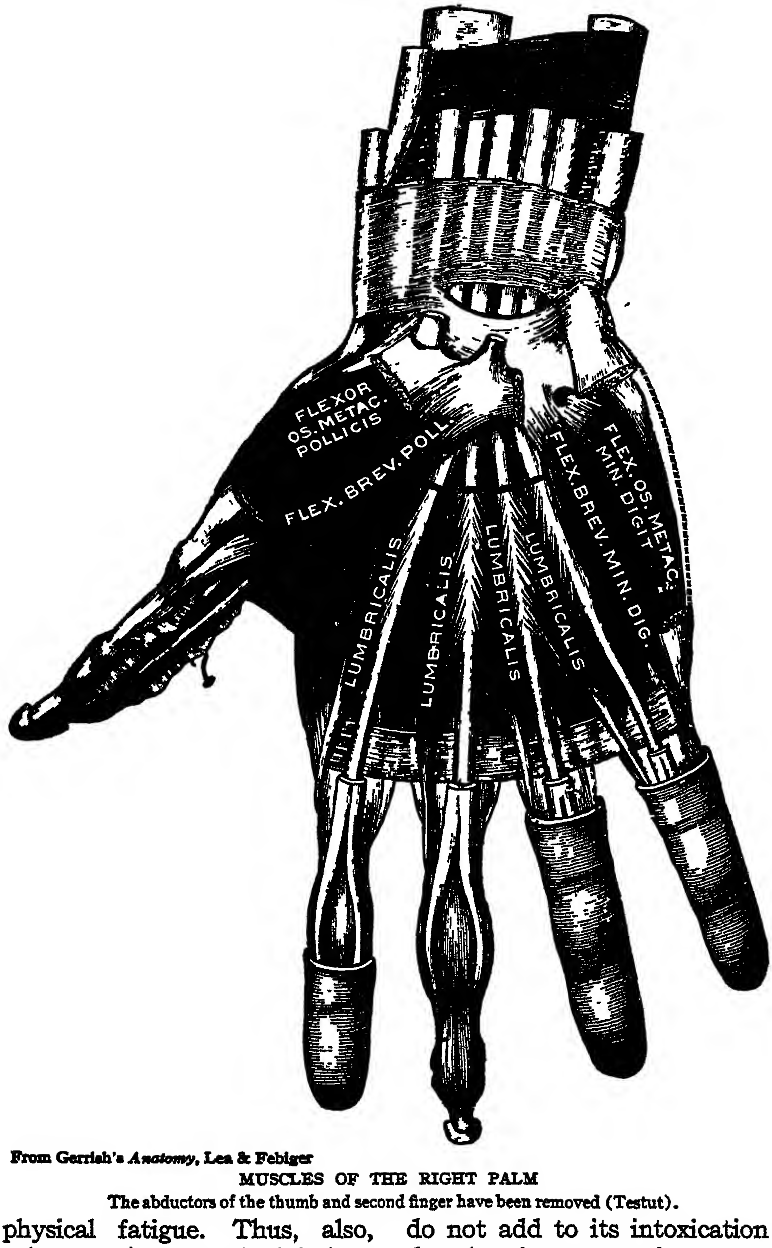
So far the facts are clear and simple. But it utterly passes the wit of man to understand how the necessary explosion or combustion occurs. It must evidently be extremely rapid. No doubt there is a good supply of oxygen, gathered from the blood, and stored ready in the muscle cells, in some form or other. But that scarcely takes us any nearer towards understanding how it is that the glucose and other fuels of muscle are able to burn, so rapidly and completely, at the mere temperature of the body — which may, remember, be a cold-blooded body — and in a state so far from dry that the whole thing occurs in a tissue which is some three-fourths water. Nor do we understand at all what happens to the substance of the muscle when the combustion occurs, so as to shorten its fibers, nor how this change is undone, in a tiny fraction of a second, so that the muscle returns to its former state. There is a key to these facts, and it may be contained in the word "ferments."

If only by the intervention of ferments can these processes be set in motion, then only by the study of ferments shall we get much further in satisfactorily explaining these interesting phenomena.

A contracting muscle produces chemical substances which have to be disposed of, like the combustion-products of any other machine. The stream of blood leaving a muscle carries away the carbonic acid gas which is the chief result of combustion here, as in every other case where carbon is completely burnt, and carbon is one of the chief constituents of glucose. Water is also produced by the combustion of the hydrogen which is also contained in glucose, and that is easily disposed of. But there remain a number of other products of combustion, which we can scarcely yet identify and name, but which are certainly very real, and which tend to accumulate in a muscle. After a while, unless they be removed rapidly enough (as occurs between the beats of the normal heart), these waste products clog the machine, so to speak, and interfere with its working. The muscle becomes tired.

We have here made a definite assertion as to the nature of muscular fatigue, which requires justification. The fatigue of a muscle, which we can observe in the successively shorter and slower strokes written by it upon our drum, or by means of a similar apparatus connected with the human hand or finger, may imaginably be due to several causes. We require to discriminate between exhaustion of the nerve cells which rule the muscle, exhaustion of the nerve fibers which run from nerve cells to muscle cells, starvation of the muscle cells, and their poisoning by their own products. Of these possible factors of muscular fatigue, the first and fourth have been verified. Nerve fibers do not get tired, and muscles grow tired long before they have exhausted their supply of food or fuel. Muscular fatigue, on the contrary, is partly nerve cell fatigue, as the microscopic and chemical examination of long stimulated motor nerve cells proves. It follows that muscular fatigue takes much longer to occur when we observe it in a nerve muscle preparation, where no nerve cells are involved, and their place is taken by an electric current which does not tire. But when muscle becomes fatigued, the fatigue is essentially a toxic symptom — due to poisoning.

Thus we can start the muscle again by washing the poisons out of it. Thus, also, the injection of a portion of the blood of a tired dog into the body of a rested dog will induce at once the symptoms of physical fatigue. Thus, also, we find the key to the control of fatigue by, for instance, hot drinks or anything that stimulates the circulation, for this means that the fatigue products will be more quickly removed by the blood stream from the tired muscles. Thus, again, we understand the remarkable influence of massage upon fatigue. Massage and passive movement do not involve the contraction of the muscle, and therefore do not add to its intoxication; but they do what its contraction normally does — they squeeze the lymph vessels and greatly promote the removal of those fatigue poisons which find their exit from the muscle by this route.



From Gerrish's *Anatomy*, Lea & Febiger

MUSCLES OF THE RIGHT PALM

The abductors of the thumb and second finger have been removed (Testut).

So much for muscles and their physiology in general, and now we must look at the striated or voluntary muscles which constitute so much of the bulk and weight of the body, and by which we move and realize our purposes. By far the greater number of them are attached to bones, and pass over joints, upon which they act. The point or surface which is usually fixed when a muscle acts, and to which it is attached, is usually called its "origin," and the point which is moved is called its "insertion." But one may reverse these relations. Thus the biceps muscle, on the front of the upper arm, bends the elbow joint, and normally its attachment to the forearm is its insertion. But when we pull ourselves up on a bar, or when we climb, the forearms are fixed, and it is the heads or origins of the biceps — *i.e.*, the two-headed muscle — that are moved.

The real meaning of the strenuous old words "thews" and "sinews"

The details of the muscles can only be learned by long and repeated dissection, though the artist may learn something of them from the point of view of surface moldings. What matters for us is that muscles are of all shapes and sizes, and that a typical muscle has a kind of rope at either end, and a fleshy part, known as its belly, in between them. This fleshy part is the muscle proper, and all flesh, properly so called, is muscular tissue, though we say that a man is putting on flesh when we really mean that he is putting on fat. The contraction of the belly of the muscle brings its ends together, moving the intervening joint or joints, and this action is that of a lever. The biceps, for instance, illustrates the mechanism of a lever, the elbow-joint being the fulcrum, the point of insertion being the site of the power, and the hand and its contents being the weight.

The ropes of a typical muscle are called "tendons." This is the right meaning of the word and none other. The fibrous structures which inclose and bind a joint are not tendons but ligaments, the two words containing respectively the ideas of stretching and binding. We can all feel tendons upon the front of the wrist, and see them upon the back of the hand or corresponding surface of the foot The old English name for tendons is "sinews," and also "nerves." A nerve and a tendon may look and feel very similar. The gross ignorance of former days in regard to the elements of anatomy is well reflected in our language. Such words as thews and sinews and nerves have all been used with transferable meanings, though nowadays the two former should certainly be confined to the tendons of muscles.

Though the muscles of the limbs, such as the biceps, are typical, many other types exist, notably the flat, expanded muscles of the abdominal wall, which exert their action by means of flat sheets of fibrous tissue, called aponeuroses, in place of tendons. These muscles are no less important as holding the body together during rest than in their function of moving the trunk, and the question of what is called their "tone" is of high importance from the point of view of the bodily contour, and also in promoting the health and proper functioning of the abdominal contents. Other muscles have very little that can be called tendon structure at all, such as those short strips of muscle which run obliquely up and down between successive ribs and play their part in respiration.

That worried look which tells the tale of want of muscular tone

A voluntary muscle which is not contracting under the influence of the will has yet a certain tension in it, just like the involuntary muscular fibers which we find in, for instance, the blood-vessels. If the nerve to any voluntary muscle be divided, it slightly relaxes. This continuous condition of slight tension is called the tone of the muscle. It is relaxed during sleep. The tone of the muscles is a notable fact and must have meaning, but the subject is somewhat obscure. There can be no doubt as to the use of the tone of the abdominal muscles; and in many cases one of the first steps necessary for the cure of constipation is to restore the tone of the muscles which are failing to keep up the

due normal pressure upon the abdominal contents. The tone of the facial muscles is intensely sensitive, and there is scarcely a better index to the state of the health, or a more tell-tale criterion of difference between youth and age, peace and worry of mind. The haggard, jaded, "old" look too commonly observed is due to the relaxed tone of muscles which should be braced. Of course, everything sags, cheeks, mouth corners, and lower lip, and the tissues round the eyes, when the facial muscles thus fail.

The muscular energy that becomes transformed not only into force but fire

It may also be the case that the tone of a muscle prepares it for contraction and abbreviates the latent period by "taking up the slack"; a theory which is naturally suggested by the case of the runner who stretches himself, or doubles himself tense, in order to lose no time in starting when the pistol fires Lastly, it is more than probable that the tone of a muscle involves some degree of combustion, and thus produces heat, which is necessary for the life of, at any rate, warm-blooded creatures such as ourselves.

This brings us, in due order, to our final point — that second function of the muscles, which is also vital, as we found in the case of the bones. They keep the body warm. It is a fact familiar to every engineer that he only gets a portion of the energy he puts into his machine back as work or useful motion By far the greater part is converted into heat, which is useless and worse than useless for his purposes. So, also, with the energy transformed in the combustion processes of muscle. Only a fraction of it is transformed into work — perhaps about fifteen per cent, according to one estimate. The remainder is turned into heat, but this heat is neither wasted, nor does it interfere with the mechanical action of the muscle, as the heat developed in an ordinary machine so often does. On the contrary, it is all employed in maintaining the temperature of the body, or of the blood, and, through it, of the body at large.

Why we need extra clothing when we sleep

Now the blood that leaves an active muscle is definitely hotter than that which enters it The muscles are thus the fire-places of the body, and perform a second function no less vital than their first.

There is a widespread popular delusion to the effect that the processes of life are wasteful, extravagant, super-abundant and uncontrolled Nothing could be farther from the truth. Life has "drive" and "push" and "thrust," life is impatient and likes short cuts; but it hates waste. When we see what we call waste, we must look again, and will seldom fail to be rewarded The combustion processes within a muscle afford an admirable illustration of the just economy and marvelous adaptability of life — an illustration superior even to that of the bones. Needless to say, the facts of muscle combustion afford the key to the best method of keeping warm and restoring the circulation in cold weather; and they also explain, in part, why we need to cover ourselves with extra clothing when we sleep.

The group action of one set of muscles involves that of the opposing set

In the foregoing we have considered muscles themselves, and their contraction in itself. Only when we study the nervous system can we learn how this power of contraction is really employed by the body for its purposes — in a fashion far unlike that of the contractions experimentally induced by the physiologist. He can isolate and study an individual muscle, and learn much therefrom; but muscles do not act individually in the living body, except in cases of disease. Muscles act in coördinated groups, for the performance of definite actions that achieve things, such as grasping and walking; and the group action of one set of muscles involves, as has lately been discovered, a group action of another kind on the part of the opposing set of muscles; otherwise our doings would be spasmodic and unmanageable. For a muscle is simply the end-organ of a nerve

Photo X.

TOMB OF ABÉLARD AND HÉLOÏSE

THINKERS

PIERRE ABÉLARD

A Hero of Romance in the Church

PIERRE ABÉLARD was born in Le Pallet, a little village about eight miles east of Nantes in Brittany, in 1079. His father, the knight Berengar, was lord of the village, and both he and his mother, Lucia, later entered the monastic state. The boy received the name of Pierre, the meaning of the surname Abélard, given him later, not being quite clear. Although the eldest son and his father's heir, he chose a life of study rather than a military career, surrendering his rights of primogeniture and inheritance to his younger brothers. He cultivated all the sciences known to his time, wandering from school to school in quest of learning, and finally, with a view to the study of scholastic philosophy, entering the famous cathedral school of Notre-Dame under William of Champeaux, whose rival he soon became in those published theses so dear to the subtle dialecticians of the Middle Ages. At twenty-two he himself opened a school and taught with extraordinary success first at Melun, later at Corbeil, and finally in Paris itself on the heights of Sainte-Geneviève. There and at the cathedral school, where in 1113 he succeeded in obtaining a chair, he enjoyed the greatest reputation as a teacher of rhetoric and dialectics. Crowds of students flocked to him from every country in Europe, drawn by the fame of his teaching. He was a handsome and eloquent man, and had the world at his feet, when he was seized with a fatal passion for the young and studious niece of Canon Fulbert, in whose house he lived

Abélard was thirty-eight when he became the tutor, and then the lover, of Héloïse, a girl of eighteen remarkable for her beauty and her attainments. The pair fled to Le Pallet, where they were secretly married and where, at his sister's home, their son, Astrolabius, was born. Afterward Héloïse returned to her uncle's house, but again fled with Abélard to the convent of Argenteuil, where she had been educated, and here she took the veil. Enraged at this second escapade, Fulbert hired wretches to break into Abélard's room at night and brutally mutilate him. The latter determined to bury his misery in the abbey of Saint-Denis, where he took the habit of a Benedictine monk. Soon, however, he again began his teaching and attracted unfavorable attention by the irreverence of his views. He was accused of expressing heterodox opinions in regard to the Holy Trinity, was summoned to appear before the synod of Soissons in 1121, and his "Introduction to Theology" was consigned to the flames Again retiring to Saint-Denis, where he quarreled with the monks over the question whether the founder of the abbey was or was not the member of the Areopagus converted by Saint Paul, he had to flee, and selected a deserted spot near Nogent-sur-Seine, where he built a little oratory, which he dedicated to the Trinity. His retreat becoming known, former students in great numbers joined him, and with their aid the establishment

was enlarged and became a convent, which he called "Paraclete" (Comforter). He was again the subject of further persecution, due perhaps more to envy than to the hardihood with which he applied philosophic methods to theology and dialectic to the penetration of the holy mysteries Later, absolved from censure and restored to monkhood, he was elected in 1125 abbot of Saint-Gildas de Rhuys, near Vannes, on the coast of Brittany. Here for ten years he had a stormy time with the monks, who considered him too severe and even threatened his life. One service he was able to perform for Héloïse before he left Saint-Gildas. The community of Argenteuil having been dispersed, she was glad to accept his offer to establish her as head of a new religious house at the now deserted Paraclete, of which he made her abbess. For a time he visited the convent as spiritual director, but suspicions having been naturally aroused that they were renewing former relations of intimacy, the lovers decided to restrict themselves to correspondence The letters have been preserved. on his part restrained, on hers frankly passionate—the first being "an unsurpassed utterance of human passion and womanly devotion" while those that follow accept "the part of resignation, which, as a brother to a sister, Abélard commended to her."

Meanwhile Abélard was again in difficulties over his views, questioned by no less a man than Saint Bernard himself. He was denounced to the bishops of France, and a council held at Sens in 1141 condemned his teachings, and Pope Innocent II ordered his imprisonment and the burning of his writings. Abélard was on his way to Rome to appeal from this condemnation when he came, worn out, to the great abbey at Cluny, where he was received by its abbot, Peter the Venerable, who succeeded in obtaining for him from the Holy See permission to retire thither and forego his imprisonment, and there, an utterly broken man with spirit of the humblest, he lingered on a few months awaiting the approach of death. He had the scurvy and when his illness increased he was moved to the priory of Saint-Marcel near Châlon-sur-Saone, where he died on the 21st of April, 1142 His body was brought to the Paraclete Héloise died there two years later and was laid beside him In 1817 their bones were transferred to Paris and now lie in one tomb in the cemetery of Père Lachaise.

Abélard was instrumental in overthrowing the prevailing realism. It and nominalism he alike rejected He asserted that we arrive at the conception of the general from the thought of the particular, that general ideas have reality only in so far as they are the creation of the intellect His system was known as "conceptualism." His ethics were founded on the study of conscience from its subjective aspect, and were philosophic rather than religious. His influence on the philosophers and theologians of the 13th century was very great, and would doubtless have been greater on those of his own day had he not expressed himself with such flippancy and irreverence as to be always under suspicion as to his orthodoxy Out of the great gatherings of enthusiastic pupils who came to hear his independent teachings grew the idea that later was embodied in the Universities, and his influence in pedagogy was of greater importance than the opinions, often erroneous, expressed in his Latin works.

ALBERTUS MAGNUS
The *Doctor Universalis* of the Middle Ages

ALBERT THE GREAT, one of the most learned men of his time, was born in 1193 at Lauingen, Swabia, of the family of the counts of Bollstädt. He studied at Padua, entered the Order of the Dominicans in 1222, and taught theology and philosophy at Ratisbon, Strassburg (1229), Cologne and in Paris (1245), where the crowd wishing to attend his courses was so great that they had to be conducted in the open air. The square is still called Place Maubert, abbreviation of *Magister Albertus* At Cologne St. Thomas Aquinas was his pupil. Provincial for his Order in Germany in 1254, he was relieved by Pope Alexander IV in 1259 to become bishop of Ratisbon, but he retired in 1262 in order to devote himself to literary work, dy-

ing in 1280 before he had finished the most important, his "*Summa Theologiæ*" His complete works make 21 folio volumes in the edition of 1651

Albertus's erudition, extraordinary for the age in which he lived, was, above all, founded on the works of the Arabs and the rabbis. He also had a profound knowledge of Aristotle, of whom many of his books are only commentaries. With him began those subtle theories of matter and form, essence and being, which delighted the souls of the doctors of the Middle Ages. His physics are almost wholly Aristotelian "He recognized the difference between natural and revealed religion, and abandoned the idea of deducing special doctrines — like the Trinity — from reason. He held that all things in philosophy are true in theology, but that beyond the knowledge gained from philosophy is a realm where the mind must depend upon revelation. Revelation is above reason, but not contrary to it."

Chemistry owed much to the discoveries of Albertus, and his mechanical experiments and studies of natural sciences gave him a knowledge which brought on him the imputation of being a sorcerer, and even now, among simple people in Germany, he is remembered as such. His followers among the scholastics called themselves Albertists.

ANAXAGORAS

The Greek Thinker who Conceived the Thought of God

ANAXAGORAS, one of the profoundest of the ancient philosophers, was born at Clazomenæ, near Smyrna, in or about the year 500 B.C. He inherited great wealth, but a greater passion for truth, to which he devoted his life, ignoring the opportunities of politics. The intellectual environment of Clazomenæ stifled him, and he yearned for Athens, "as all energy longs for a fitting theater on which to play its part."

The Age of Pericles, unexampled before or since in the history of mankind, was at hand. The young Pericles, indeed, and Euripides, and, according to some accounts, Socrates himself, soon came to be ranked among the pupils of Anaxagoras in Athens.

Devoted as he was to the universal problems which appealed to him as to those like him in all ages, the wealthy young thinker neglected his affairs until at last he found himself penniless, whereupon he is reported to have exclaimed: "To Philosophy I owe my worldly ruin, and my soul's prosperity" As a teacher Anaxagoras soon gained fame, and at the same time incurred the jealousy of unworthy rivals, who, taking the great name of Religion in vain, brought accusations of blasphemy against the thinker whom they could not and would not understand in his attempts to enlarge men's notions of Deity. Arraigned, tried and condemned to death, he escaped with his life, thanks to the intervention of the great statesman Pericles.

He was sentenced to lifelong banishment, and went to Lampsacus, where he spent the rest of his life. In Athens he had taught the truth as he saw it for some thirty years, but this was his reward, and he may be forgiven for his proud remark, "Not I have lost the Athenians, but the Athenians me."

Many difficulties face the scholars who seek to state, in our language and terms, the beliefs and teaching of so remote a thinker, none the less because, like many another, even of such high rank, Anaxagoras did not necessarily teach one and the same consistent doctrine throughout his life.

Yet, though we cannot be sure as to many things, the main tenets of this pioneer may be defined clearly enough. He was, in the first place, a man of science in his belief that many physical phenomena, vulgarly attributed to the caprice of "the gods," were really produced by natural causes.

In this and in other notable respects Anaxagoras was certainly a follower and expounder of his illustrious predecessor, Thales. We can readily understand that the cry of atheism might be raised against a teacher who found natural causes for such phenomena as the heat and light of the sun, and who could predict eclipses, as against the view that such forces and events were immediately directed by "the gods."

Anaxagoras recognized the doings and material structure of the physical world to depend upon the combination and interaction of elementary and simple units which we may accurately enough call atoms, so long as we do not include in that term all the ideas of modern chemistry. The question that remained, above and below all, for him to answer was the *cause* of these combinations and interactions, including those of which living beings are the most subtle and astonishing examples.

His answer was given in his sublime and noble doctrine of a universal mind, or "Nous," to use his own term, which is the prime mover of the universe. As ever and ever again in the history of thought, we observe that the so-called "atheist" is often he who has ideas of God too great for small minds to hold. Anaxagoras considered the claims of Fate and of Chance as the masters of the world. In the first he saw a mere name for what we do not understand, putting off our questioning and explaining nothing In Chance, profound anticipator of later thought as he was, he recognized merely the action of law under forms which our reason cannot suffice to define. Only Intelligence was therefore left as the possible disposer and mover of the world — Mind Infinite, Eternal, Universal, which, to quote the thinker's own words, "knows and arranges all things that ought to be, that were, that are and that will be."

It is not possible to find earlier in the history of thought so complete and sublime a conception of Deity as this philosopher framed; and if we call theology a science, as indeed it is, then Anaxagoras may well be named its father.

He died at Lampsacus on the Hellespont in 428 B.C., thinking great thoughts to the end; and when he was asked to name a memorial for himself, he replied from his death-bed that it was his wish that the day of his death should be a holiday in the schools of the city, a request which was complied with for centuries thereafter. And over his grave was written this epitaph:

This tomb great Anaxagoras confines,
Whose mind explained the heavenly paths of Truth.

ANAXIMANDER
The Man who Took a Great Step Toward the Truth

ANAXIMANDER, one of the earliest of natural philosophers, was born at Miletus in 611 or 610 B C, and may be ranked as the successor of Thales. It is principally to Aristotle that we owe our knowledge of him and his achievements, which must have been very great in certain directions His observations of the heavens enabled him to construct what was presumably the first sun-dial, and his study of the surface of the earth led him to sketch a kind of map, so that he may be called the first cartographer. He is said also to have declared that the moon shines by light derived from the sun; and he is, perhaps above all, justly famous for his assertion of the belief that the earth was cylindrical in shape This colossal assertion, so great a step towards the truth as we know it, was first conceived, so far as any record goes, in the brilliant mind of this student. He was, however, more than an astronomer. His devotion to mathematics and to mathematical ideas led him on to speculate as to the ultimate nature and origin of things His conclusion was that things have their origin in the Infinite, but it is clear that his conception of the Infinite did not comprise the idea of mind, which was for him only a terrestrial and ephemeral product, as for materialists in all times. To their number, in polar contrast to Anaxagoras, this early philosopher belongs. He is said to have died about 547 B.C.

THOMAS AQUINAS
The Angelic Doctor of the Darkest Centuries

ST THOMAS AQUINAS, the greatest figure of medieval Scholasticism, was born in or about 1227, and belonged to the noble family of royal blood of the Counts of Aquino, a town between Rome and Naples He was a born student. Six years at the University of Naples were enough to make him a fervent follower of learning where it was best to be found. Thus, at the early age of sixteen, and against the earnest wishes of his parents, overcome only by the intervention of Pope Innocent IV, he became a Dominican.

This was perhaps the best thing that could have happened to him. The most famous thinker of the time, Albertus Magnus, became his teacher and the young Thomas of Aquino learned with ardor and ease all that was set before him From the beginning to the end of his comparatively short life he was a tremendous worker, and has left behind him not merely an influence which dominated the thought of western Europe for centuries, but also an astonishing quantity of actual writing, much of it original, and much of it of the nature of commentaries, which display an insatiable and apparently untiring studiousness.

To this he was born, and nothing could stop him. The parental opposition which had kept him a prisoner in his father's castle for two years was not enough to check so intense a love of knowledge, even in a man whose gentleness of disposition, consistent courtesy and piety were ere long to earn for him the title of the "Angelic Doctor," by which he has been ever since known.

Any attempt to understand or appreciate this remarkable man must be based on a clear understanding of the time and circumstances of his life In order to know him we should know the thirteenth century. All the learning that there was was in the hands of the Church, which Aquinas ardently loved and believed in. But with this love and faith of his, and acting throughout all the years of his initiation into Roman Catholicism, he had also one of the most acute, eager and profound intellects of which we have any record. Any form and order of knowledge was grist to his mill; but all the while his faith in what Holy Church taught made it necessary for him to reconcile the findings of science with her dogmas. In this Aquinas was, perhaps, of all men of all times the best qualified for the purpose.

Though he was himself ignorant of Greek, he obtained access to Aristotle in Latin, and became the great introducer of the "master of them that know" to the medieval and modern world. He sought to include all Aristotle's findings in a complete scheme of knowledge of human and divine things; and though nothing but first-hand and prolonged study can reveal to us of today the full nature of Aquinas's task, we may dimly imagine what it meant to accept the independent "pagan" thinker, logician, naturalist and moralist, and at the same time to bring him into harmony with Roman Catholicism. The result of this attempt was the marvelous product of the human mind which is called Scholasticism, and of those who labored at its making St. Thomas Aquinas is the acknowledged master and center. At this very hour the influence of the schoolmen, and thus of Aquinas above all, is paramount in the system of Roman Catholic learning.

Aquinas possessed one of the most powerful and subtle intellects of which we have record; and we have already seen with what assiduity its possessor used this masterful machine of his. Rapidity and confidence must have marked his logical processes, for he found time to make many journeys, and play a great part in the practical and political life of the Church in his time. Few men have enjoyed more honor and fame for their intellectual powers than this sweet-mannered man and stern logician; and successive centuries have only added to his reputation in the Church which he served so well.

The greatest work of Aquinas was his comprehensive treatise the "*Summa Theologiæ*," in which, after many preceding years of labor, he sought to summarize the whole of human knowledge in its due relation and proportion as part of Theology, or the Science of God. His other great book was his "Sum of the Catholic Faith against the Gentiles," which is usually referred to by the last two words of its original title, as the "*Contra Gentiles*."

Aquinas believed that there were two sources of truth: revelation and reason. They are not contradictory because, in the last resort, they rest on one absolute truth — they come from the one source of knowledge, God. Hence the compatibility of philosophy and theology, and the possibility of a *Summa Theologiæ* which shall be a *Summa Philosophiæ* as well. In his second book he shows that Christian theology is the sum and crown of all science.

Living for learning, Aquinas consistently refused ecclesiastical preferment. He had no time to be an archbishop or an abbot, though such offices were offered him. But he was required none the less in the councils of the Church, and was constantly consulted by the reigning pontiff. On his way to such a council, in the earliest days of the year 1274, and already ill, he was struck down so that he could not continue his journey Thus on the route from Naples to Lyons, he died on March 7, 1274 Few men have been the possessors of greater powers, or have used them more faithfully.

Aquinas was canonized in 1323. In an Encyclical of Pope Leo XIII the clergy were directed to take his teachings as the basis of their theological instruction, and in 1880 he was declared patron of all church educational establishments.

ARISTOTLE
The Master-Thinker of the Ancient World

ARISTOTLE, who sought to unify all knowledge, and was "the most profound and comprehensive thinker of the pre-Christian world," was born in the year 384 B.C. at Stagira, in Macedonia, the son of a physician. As a young man, he was doubtless expected to follow the family profession of doctor, and had prospects of success, for his father was medical adviser to both the grandfather and the father of Alexander the Great. But one branch of knowledge was too narrow for Aristotle. Like Bacon, he took all knowledge for his province, till he became, as Dante said, "the master of those who know."

His life was varied and romantic for a man of thought. In his eighteenth year (367 B.C) he made his way to Athens as a student, presently became a frequenter of Plato's academy, and so continued, more or less, till middle life, though he also set up a school of his own for oratory — a valued part of Athenian education. After Plato's death, in 347 B.C., he left Athens and lived for three years in the town of Atarneus, in Asia Minor, where the ruler, Hermeias, was a pupil and friend from Athens. After the death of Hermeias, Aristotle married a sister of his friend, and lived for two years in the island town of Mytilene. Thence he was invited by Philip of Macedonia to undertake the education of his young son Alexander, and for three years Aristotle was the preceptor of the would-be conqueror of the world Afterwards Alexander declared that he loved and revered Aristotle as much as he loved and revered his own father, for "he was indebted to the one for life, and to the other for living well"

When Alexander set out on his career of conquest, Aristotle, who did not approve of the enterprise, returned to Athens, but he no doubt remained there a cordial supporter of Macedonian interests. During the next twelve years Aristotle did the work which, as has been said, gave him command of the thought of the world for a thousand years. Establishing a school called the Lyceum in "The Walk," near the temple of Apollo Lyceius, he developed his philosophy for the advantage of his followers, until practically the whole of the then known knowledge of the world began to systematize itself in his mind, and he conceived the idea of producing a complete cyclopedia of philosophy, on lines that we should now call scientific. Large sections of the work were planned, and some were fully thought out and filled in, in writing — as, for example, a treatise on logic that was entirely original, and has never been superseded. Other sections were left as bare outlines, and some as magnificent fragments, when, on the death of Alexander, jealousy began to conspire against the life of the great teacher, as it had conspired before against the life of Socrates, and, as a precaution, Aristotle retired to Chalcis in 322. His health had been impaired for some time, and in the same year, at the age of sixty-two, he died.

The perpetuation of his influence is one of the great romances in the history of thought. His followers were not capable of expanding, or perhaps even of interpreting, the system of thought he had striven to bring into being, though they continued to discuss fragments from it, and wrote sectional treatises which, later, were accepted as his. Other schools of thought arose — the Stoics and Epicureans — and

drew away attention by their controversies, so that his influence waned in the city where he had done his life's work, but had always been a stranger. Then his writings, bequeathed to his chief disciple, were handed on to that disciple's literary heir, who carried away the manuscripts to Asia Minor and carefully hid them from a local king, who was forming a library by the kingly process of "requisitioning" It was not till nearly two hundred years later that these writings were returned to Athens There they were seized, carried to Rome, and carefully collated and edited

men were not ready to understand the writings of a fearless inquirer like Aristotle, who was not bound by precedent, but wished "to investigate all that can be known, and to express what he found exactly and exhaustively." And even now some hasten to misjudge him, through failing to realize the conditions under which he lived and thought.

We must be content to accept such facts as that Aristotle's philosophy was only intended to refer to a twentieth of the people around him; that it was a flattery of 20,000 superior persons living on the labors of 400,000 slaves who could have no participation in liberty or in property; that it asserted the impossibility of "caring for the things of virtue while living the life of the artisan or the slave"; that it excluded the mechanical and useful arts as involving work too servile for the attention of a free man; and regarded women as essentially inferior to man, and incapable of sharing his intellectual privileges.

ARISTOTLE, THE MOST PROFOUND AND COMPREHENSIVE THINKER IN THE WORLD BEFORE CHRISTIANITY, INSTRUCTING A PUPIL IN ATHENS

Meantime, spurious works had been circulated in the name of Aristotle, and the scope of his work, the true significance of his thought, and even the qualities of his style, were misjudged by the writers of Rome in his day of literary predominance. And later, when what was supposed to be Aristotle's philosophy was accepted largely by the medieval schoolmen, and was made the basis of much of their teaching, it was a version taken not from his original writings, but accepted from the Arabic versions of Avicenna and Averroes, which had been translated from Greek into Syriac, and then into Latin, with accretions of Oriental thought by the way. The fact is that before the great revival of learning and the outburst of freedom which followed,

We may wonder that such a great thinker could have suffered these limitations in his deliberate philosophy, but it is a far greater wonder that one living in an age which accepted these ideas as matters of course could have mapped out the world of mind so completely, and be hailed as "the father of nearly all the modern sciences."

The divisions of learning in our great universities today are Aristotle's divisions. In some of the sub-divisions he almost said the last word. The very language in which we express our abstract ideas is adopted from his phraseology. Whether we speak of philosophy or physics, of metaphysics or biology, of physiology or psychology, of ethics or logic, or economics, or politics, of poetry, or oratory, or the drama, or criticism, of natural history or astronomy, of hygiene or education, or even the weather, he has been there before us, sometimes, it may be, with little knowledge, but always with keen analytical insight. Though he lived before the greatest physical laws of the universe were discovered, he has been described as "by common consent the best educated man of any age, with the greatest influence on subsequent times."

SAINT AUGUSTINE
The Greatest of the Latin Fathers

SAINT AUGUSTINE, Doctor of the Church and one of the world's greatest thinkers, was born on November 13, 354, at Tagaste, a small city of Numidia, in northern Africa. His mother, Monica, was a devout Christian although his father, Patricius, was a pagan and remained such until near the time of his death. He himself in his early years was enrolled among the catechumens, and his first education at Tagaste was Christian. His success in his literary studies made his father resolve to send him to Carthage. He arrived there in 370 and soon became captivated by the seductions and the licentiousness of the great city. He himself describes this period of his life in the second book of his "Confessions" and tells us of his pursuit of unlawful pleasure and of the remorse which from time to time filled his soul, without giving him strength to break the chains which passion had forged for him. A perusal of the "Hortensius" of Cicero awoke in him that interest in philosophy, especially in its relations to the Christian faith, which characterized so much of his later life. In his nineteenth year he became attracted to Manichæism and for nine years ardently defended its doctrines without, however, finding in them that intellectual satisfaction for which he craved. After his studies, instead of entering upon a forensic career, as his father had planned, Augustine taught letters at Tagaste. In 383 he went to Rome and opened a school of rhetoric Being disgusted with his pupils, he went to Milan, where he obtained a professorship Here he came under the influence of St Ambrose, bishop of the city, who was destined to change the whole course of his life. He followed the bishop's sermons and, after some three years of mental struggle, was baptized by him at Easter, in 387.

Augustine had already begun to carry out the desire he had conceived of devoting his life to philosophy. After his baptism he resolved to return to Africa and seek a higher life in solitude with his friends Alypius and Evodius His mother, Monica, who after years of prayer and many tears for the aberrations of her illustrious son had at last been rewarded by his recent conversion, was about to embark with him at Ostia when she fell ill and died there.

Augustine's account of her last days and of his intense grief at her loss form some of the most touching pages of his "Confessions." Upon his return to Tagaste, he sold his property and gave the proceeds to the poor and began with his friends a life devoted to prayer and to the study of the Scriptures. He seems at this time to have had no thought of entering the priesthood. His growing fame as a writer and his remarkable conversion from Manichæism and from a youth of dissipation had made him known in spite of his desire of solitude. While on a visit to Hippo, the people begged their bishop, Valerius, to confer Holy Orders upon him. In spite of his reluctance, he was ordained priest in 391 and immediately devoted himself to preaching. His success was great, and such was the esteem the bishop entertained for this leader among his clergy, that he made him his coadjutor, and Augustine was consecrated bishop by Megalius, the Primate of Numidia. He succeeded Valerius and spent the remainder of his life as bishop of Hippo.

While whole-heartedly devoted to his flock, Augustine at the same time became known as the greatest expounder and defender of the Catholic faith of his time He preached frequently, took part in various councils held in Africa, wrote numerous doctrinal and exegetical treatises, engaged in theological controversies and carried on an extensive correspondence His last years were saddened by political disturbances in Africa. His episcopal city was besieged by the Vandals. He strengthened the courage of his people but fell ill at the beginning of the siege and passed away before its end.

SAINT AUGUSTINE AND HIS MOTHER

St. Augustine's life was written by Possidius, a friend and disciple for nearly forty years. His "Confessions" give us the best insight into his mental and spiritual life, while his correspondence and various writings, together with the opinions of his contemporaries, give us an intimate knowledge of the character and genius of this great Doctor of the Church. He possessed a great and generous soul. Even in his youthful aberrations he never lost his keen sense of honor, nor did he altogether forget his lofty ambition and high ideals. He had a heart capable of giving and inspiring great affection, and from his boyhood he was filled with a passion for truth. After his conversion he was conspicuous for personal holiness. As a bishop he led a simple, frugal life with the clergy of his household and, as his biographer remarks, made no will before his death because he had nothing to bequeath to those who came after him.

As has been stated, Augustine in his youth adopted the tenets of the Manichæans. This strange sect seems to have attracted him by its philosophy without faith and by its denial of liberty with the attribution of evil to a foreign principle. Its claim to find contradictions in Holy Writ doubtless justified in his own mind his refusal to embrace the Christian faith. He hoped also to find in its doctrines an explanation of the mysteries of nature. He was gradually disillusioned as he came to know more of the nature of the whole system, and after his ordination and later as bishop he strove with ardent zeal to convert his former fellow believers. He succeeded in winning over Felix, the great doctor of the sect.

Shortly after taking possession of the see of Hippo Augustine became involved in the famous Donatist controversy.

This movement, which made a considerable stir in the Church, was started in Africa by the refusal of the bishops of Numidia to accept as valid the consecration of Cælian, bishop of Carthage, by a "traditor," that is, by a bishop who had delivered the sacred books of the Christians to the persecutors Augustine in various councils tried to reconcile the Donatists with the Church. A solemn conference took place in Carthage in 411 at which he was the leading spokesman. Here he vindicated the Catholic position and the schism gradually died out. In the meantime there rose a grave theological dispute of far greater consequences to the Church concerning the questions of human freedom and divine grace and the relations existing between them Pelagius, who took refuge in Africa about that time, was the author of a system, named after him "Pelagianism," which denied original sin and, making the human will independent of God, also made man capable of perfection without divine grace Augustine entered the lists against the Pelagians with such skill and success as to merit the title of "Doctor of Grace" While defending human liberty, he insisted upon the necessity of God's grace for every good act and for salvation. The doctrines of Pelagius on original sin were condemned by a council held at Carthage in 412 Augustine continued to write against them and also brought the true nature of their teaching to the attention of Pope Zosimus, who solemnly condemned them in 418.

St. Augustine, like many others of the early Fathers, wrote numerous commentaries on Holy Writ. With an interest in the world of nature that dated back to the days of his youth, he devoted many years to a study of the problems connected with the creation of the world and the beginning of the human race as narrated in the book of Genesis. These problems have assumed a new importance during the past half century or more in connection with modern scientific discoveries and the development of the various theories of evolution, and Augustine's commanding position as a Father of the Church and as one of the greatest minds of his epoch gives special interest to his views He distinguishes between the simultaneous creation of the world and its subsequent gradual development to its present state under the action of the forces of nature implanted in it. According to him, God in the beginning created the elements of constituents of the world in the form of a nebulous mass. Some of these elements were substantially as they are now, and this is especially true of the inorganic world, while others existed only in germ to be developed later under favorable conditions. All living beings in particular existed from the beginning, but only potentially or in germ, and were destined to assume their proper form in the course of time Thus Augustine fully realized the important part growth and development have played in the formation of the world. He compares this evolution to the slow growth of a tree from a seed.

Evolution, however, as conceived by Augustine, was not one due to mere chance nor was it the result of the action of blind forces. The germs or *rationes seminales*, with all their activities and potentialities, of which he so often speaks, were implanted by the Creator in the very beginning. Their development in the course of time was due to the latent powers within them. While he even admitted that Adam and Eve also existed from the beginning in a certain sense potentially or causally, he accepted the scriptural account of their formation. It does not appear that he admitted the transformation of one species into another.

St. Augustine was a prolific author While most of his works are of purely philosophical or theological value, two of them, the "*De Civitate Dei*" and the "Confessions," are of universal interest and have appealed to every age.

The latter illuminating autobiography, which is perhaps his best-known work, gives with touching humility and frankness the history of his own soul. It abounds in passages of surpassing beauty. The former is a masterpiece which analyzes the nature of Divine Providence and shows Christianity rising in majesty upon the ruins of the Roman Empire.

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